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Measurement and Modeling of Human Performance Under Differing G Conditions

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FOR THE DIRECTOR

//Signed//

MARK M. HOFFMAN
Deputy Chief, Biosciences and Protection Division
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14. ABSTRACT
A synthesis of past literature on cognitive skills identified by pilots as being critical in the acceleration environment was performed. These skills include various kinds of decision making, tracking, spatial orientation, time/velocity estimation, perceptual speed, visual function, and instrument reading. Since the literature base on these skills is far from complete, a new test battery designed specifically to address these cognitive skills was developed. The "G-Performance Assessment Simulation System" (G-PASS) consists of twelve cognitive performance tests designed to be used in the centrifuge, and consists of both 'stand-alone' tests and others that are presented within an aerodynamically accurate simulation of the F-16 aircraft. In addition, to utilize these data in a user-friendly model, the "G-effective" hemodynamic model developed previously has been adapted to the available performance data. The end product of these efforts is the "G-Tool to Optimize Performance" (G-TOP). This is a model-based graphical presentation of the second-by-second effects of any G profile on nine cognitive functions. The user simply specifies the desired profile and the decrement in each cognitive function is automatically calculated and displayed as an integrated, dynamic picture - a "Cognitive Vulnerability Map" (CVM).

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PREFACE

The work supporting this report was carried out under a Phase II Small Business Innovation Research (SBIR) contract from the USAF Air Force Research Laboratory. The contract technical monitor for this effort was Capt Kathy Fullerton who, along with Dr. William Albery and Dr. Tamara Chelette provided invaluable technical advice and support. Additional software and training support were supplied by Lloyd Tripp, Andy McKinley, Bob Esken, and Amanda Reeber. Their assistance is greatly appreciated.

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EXECUTIVE SUMMARY

This document outlines the general processes involved in a new technology developed by NTI, with the assistance of Dr. Dana Rogers, to produce a tool that will: 1) summarize data from many sources on the cognitive effects of a given stressor, 2) provide a cognitive model that will estimate effects where data are missing, 3) relate values from this model to various real-world jobs, and 4) present the results in a dynamic, graphical way so that users can determine how best to manage the stressor to produce optimal performance. This general procedure was developed under an SBIR contract with NTI devoted to developing a human performance model of cognition under acceleration stress. This contract resulted in a specific cognitive performance test battery -- the "G-Performance Assessment Simulation System -- G-PASS", which is a standardized battery of performance tests specifically directed to assessing pilot cognition under high G loads. In addition, however, the "G-Tool to Optimize Performance -- G-TOP" was developed incorporating the human performance model.

The sections of this Executive Summary describe this technology in general terms, focusing on the original centrifuge application. Their purpose is to summarize the various elements of the project, explaining the rationale and thought processes that went into it. Detailed technical aspects of the G-PASS and G-TOP developments are presented in the following full report for the SBIR contract.

Current State of Centrifuge Research In Cognitive Function

Centrifuge research has progressed in many ways, beginning with basic physiological protections that assist the individual to sustain high levels of acceleration force (e.g., G- suits, positive pressure breathing, etc.) as well as ergonomic advances that decrease the time between the approach of an enemy target and the action taken by the pilot (e.g., digital signal processors, head-related transfer functions). Today much is known about the physiological response of the human on the centrifuge, leading to effective methods of improving performance and tolerance.

On the other hand, the effect of acceleration forces on <u>cognitive performance</u> is much less well known. Although many studies have been carried out focusing on specific aspects of cognition under increased gravity (G), there has been no attempt to generalize these into a model or even a methodology that would permit prediction of cognitive performance during and after increased G exposure. The present technological innovation constitutes the first such attempt at a comprehensive modeling approach, and provides such a tool for predicting, and ultimately enhancing human performance during and after increased G exposure.

The first task in developing a G-dependent model was to survey and, more importantly, to summarize past literature pertaining to critical cognitive processes at various levels of acceleration forces (see Section One of this report). This effort revealed a considerable data base on these topics, but little coherence among the various studies. Although some were reported in sufficient and useable detail, others reported data in ways that were hard to summarize. There were confusing metric units, exposure conditions that were poorly specified, and statistical analyses that were vaguely described. As a result, much of the literature that was surveyed was not useable in formulating any coherent methodology and model. However, even given the above, it was possible to plot the more consistent studies on common baselines, and to discern generalizable trends in the data for specific G-related conditions (the effort focused entirely on Gz exposures, although the methodology is entirely generalizable to Gx and Gy exposures). From this, it was then possible to select "prototypical" studies that appeared to capture these trends. In this way, the considerable and sometimes bewildering literature base on cognitive functions under various acceleration forces were reduced to a manageable set of values that represent the best detailed scientific estimate of the effect of acceleration forces on cognitive functions.

However, a major problem in such an approach is defining "cognitive functions", and more generally, what the operational impact of those functions might be. Psychologists have typically defined such functions in terms of the tests that are used to probe hypothesized "skills" or "attributes". This has led to a situation in which experimental dependent variables determine whether a hypothesized skill is degraded under a given stressor (e.g., G forces). The operational expert (the warrior) then says "so what?" In other words, what does it mean in the real world (of the fighter pilot) if there is a 100 msec. decrement in reaction time? Obviously, there was a need to create a "link" between the centrifuge results and "relative effectiveness" of the operator.

A beginning to creating such a link was made in a conference held at WPAFB in which researchers and operational personnel discussed the cognitive processes that were essential to safe and successful fighter operations, and particularly those that might be degraded by high-G environments. A list of tasks was produced at this conference, primarily phrased in terms of the fighter pilot's operational objectives (see Table 1 in this report). This list provided a form of task analysis of "critical skills" of interest in the present context. These could then be analyzed by cognitive psychologists, and translated into more basic skill or process terms that could correspond to those used in traditional centrifuge experiments. In other words, a bridge was created between operational skills that warriors considered important and basic skills that researchers typically measure. This, in effect, provided a blueprint for selecting those skills that needed to be considered in any model of meaningful acceleration effects on the human.

Development of the "G-PERFORMANCE ASSESSMENT SIMULATION SYSTEM" -- G-PASS

The literature review carried out by NTI demonstrated a need for some degree of standardization in the tests used by acceleration researchers. Variation in methodologies clearly was hindering formulation of any comprehensive model of cognitive effects. The time appeared opportune to make progress in such standardization, since advances in cognitive modeling were beginning to define the universe of relatively independent cognitive processes. Neuro-imaging studies were beginning to isolate specific brain areas that become active during specific cognitive tasks, permitting levels of cognitive skill definition that were previously done primarily on an "armchair" basis. NTI therefore set about developing performance tests that would be structured around current concepts in cognition. In doing this, the definitions and blueprint described above became critical elements in selecting and designing tests that could be related to critical operational flying tasks.

The result of the exercise to convert the flight-relevant terms in the pilots' definition of critical skills to the cognitive processes demanded is summarized in Table S1, and defined more fully in Section One of this report.

TABLE S1

COGNITIVE PROCESSES CONSIDERED ESSENTIAL IN THE ACCELERATION ENVIRONMENT

SPATIAL ORIENTATION
MOTION INFERENCE (SLOW AND FAST)
TRACKING
SIMPLE DECISION MAKING
COMPLEX DECISION MAKING (REACTION TIME, ACCURACY, AND EFFICIENCY)
VISUAL ACUITY
INSTRUMENT READING
PERCEPTUAL SPEED

During the course of the Phase I and Phase II efforts, a total of 12 tasks were developed which attempt to probe these skills to varying degrees. Taken together, this "G-Performance Assessment Simulation System -- G- PASS" represents the most complete battery of tests ever developed specifically to assess the critical cognitive processes that might be degraded in the high performance flying environment. These tests are listed in Table S2, and are described in detail in Section Two of this report. A detailed Users' Manual is presented as Appendix B.

TABLE S2

THE G-PASS TEST BATTERY

Test 1: Perception of Relative Motion
Test 2: Precision Timing
Test 3: Motion Inference
Test 4: Pitch/Roll Capture
Test 5: Peripheral Vision
Test 6: Rapid Decision Making
Test 7: Basic Flying Skills
Test 8: Gunsight Tracking
Test 9: Situation Awareness
Test 10: Unusual Attitude Recovery
Test 11: Short-term Memory with Distraction
Test 12: Visual Monitoring

Although the above test battery attempts to focus on the "critical processes" essential to safe and efficient flight in the acceleration environment, it does not differ appreciably from batteries that could be constructed with existing tools (e.g., the ANAM or UTC-PAB batteries). In its elementary form, it would still remain a primitive "armchair" battery. To bring it a measure closer to a quantifiable technique for matching tests to the critical demands of a job, an additional innovation was required. This innovation, the T-Matrix, is described briefly in the next section, and in detail in Section Two of this report.

The T-Matrix concept

It is obvious that any one performance test does not measure a single cognitive function. Even a simple reaction time test, while it may primarily probe speed of response, also taps into such cognitive functions as attention allocation, vigilance, visual-motor control, response inhibition, and perhaps others. At the same time, two or more tests can provide complementary information about a particular process. The Educational Testing Service (ETS) has recognized that this is also true of individual test items, and has developed a technique that accounts for the overlapping characteristics of single test questions. The technique has been termed the Q-Matrix (for "question matrix") approach. Essentially, the technique attempts to derive vector weights for the test items that describe how much the individual test questions probe specific knowledge or attributes within a skill. This is done by creating a matrix listing attributes in one dimension and test items or questions in the other. Expert opinion is then used to determine whether a test item does or does not require a given attribute. Boolean algebra generates vector descriptions of each question based on the degree to which that test item probes the attributes that the entire test is purported to measure.

It appeared that this approach might be able to be adapted to generate estimates of the degree to which a given G-PASS test probes each critical cognitive process required by the pilot. This approach has been designated as the "T-matrix" -- since it involves tests rather than questions. In it, the cognitive processes critical for successful flight performance are listed in one dimension of the matrix, and the G-PASS tests are listed in the other. To implement this approach, a panel of NTI scientists was asked to determine "to what degree each G-PASS test probes each critical cognitive process." From these values, the vector values for each process with respect to each G-PASS test were determined. These were then combined with estimates of the "criticality" of each cognitive skill to a representative flying mission, and optimization algorithms were applied in order to select the optimum combination of G-PASS tests to probe each of the critical cognitive processes involved in that mission. In Section Two of this report, a "proof of concept" demonstration of this technique is presented.

By using the T-Matrix, the researcher can be assured that cognitive processes essential to the mission are tested and some degree of quantification (although still based on expert opinion) is achieved. The T-matrix differs from all previous techniques in providing an objective audit trail of the rationale for test selection. It provides three major advances over these past approaches: 1) It allows for a limited, optimum number of tests to be used for any application, 2) It allows for a "checks and balances" system to be sure each desired cognitive process is being measured to a strong degree and that more than one test does not measure the same degree of each cognitive process, and 3) It provides the flexibility to include cognitive demands that may change as the nature of a job changes.

Development of a Model of Cognitive Performance in the Acceleration Environment

In a crude sense, the list of critical cognitive skills in high performance flying described above constitutes a model of the acceleration environment. It constitutes a first attempt to describe the cognitive aspects of the task. It also identifies the data that will be required to make any model useful as input to more extensive "systems" models, such as CART. The problem is that, in the acceleration literature, the data on cognitive functions are sporadic and inconsistent. As noted above, although some data might exist on each of the functions that should be included in a model, there are large gaps in the G levels studied, inconsistencies in methodology, and variations in statistical analyses and reporting.

One of the first tasks in the present effort was to try to make sense out of this literature. Most importantly, once reliable studies had been identified, the varying metrics had to be "normalized" so that studies could be compared to each other and integrated so that we had as much valid data on each skill as possible. To accomplish this, a series of normalizing formulae were created, using 1G data as "baseline" and translating measured effects of the various G levels used in the studies to a "percent decrement". The techniques used to do this are described in detail in this report. This permitted us to construct a matrix showing what data were available in the literature on the decrement in each skill at each G level studied.

Unfortunately, the resultant matrix was still quite anemic. There were many G levels that had never been studied, exposure durations were so varied that it was difficult to add a "time" dimension to the matrix, and onset rates were either poorly specified or, sometimes, not specified at all. Obviously, the literature matrix developed in this way would not be useful as input to systems models. The initial plan to remedy this problem was to gather a group of individuals highly experienced in centrifuge research, either as subjects or experimenters, and have these "subject matter experts" fill in the missing data with their best estimates. However, this was never considered to be a satisfying approach, and a more "objective" technique was actively sought. This objective approach appeared in the "G-effective" model developed by Rogers (2003). NTI's adaptation of this model is briefly described below, and in detail in Section Three of this report.

The G-Effective model

Dr. Rogers independently developed a model of the effects of acceleration on the human's physiological response. The model is based on the fact that the body does not respond linearly to the application of an accelerative force. Rather, there are a complex series of lags, overshoots, and adaptations that affect the time course of the human's response. The result is that a given level of imposed G force will not always have the same effect on the person at a given time. Rather, the true "effective" G load on the person will depend on factors such as the rate of onset and the duration of exposure. Dr. Rogers utilized physiological hemodynamic data and models to calculate the body's response, and developed a generalized model that is applicable over any onset rate and duration for a given G load. With it, one can specify a G-profile, and determine the actual "G-effective" that is being imposed on the person (and affecting cortical and sub-cortical perfusion) at any time. Dr. Rogers applied this model to some previously gathered tracking data, and found excellent agreement with the model's performance predictions and actual performance.

In consultation with Dr. Rogers, NTI suggested that <u>the literature matrix described above could be used as input data to the G-effective model, and that the model could then extrapolate from the existing data to provide estimates of the decrement for durations and G load where data did not exist.</u> In other words, using actual data as "tie-down" points, the G-effective model would establish what effect the person's physiological state was having on the performance of a given skill. Skill decrements consistent with those tie-down points would then be calculated for the missing data. In this way, the initial "matrix" could be filled in. In addition, however, several other dimensions such as duration and onset rate could also be considered. This complete matrix was then developed by NTI and Dr. Rogers, and constitutes the fundamental data base underlying the model of cognitive performance under acceleration.

The G-tool to Optimize Performance (G-TOP)

The matrix described above yielded an extensive, quantified description of the effect of acceleration on cognitive performance. The description is able to take into consideration differences in onset rates, duration of exposure, and G-profile. Through use of the G-effective model and its estimates for missing data, this final matrix represents the most complete description of the effect of acceleration on individual cognitive processes ever compiled.

However, in matrix form, the practical applications of this information are somewhat limited. It is true that the data could be imported into systems models and be used to modulate performance estimates. However, one of the initial goals of this effort was to provide a way for the researcher or operational commander to 'experiment' with different profiles in order to optimize performance. What was needed was a technique that would allow the non-specialist to assess overall cognitive effects in an easily interpreted way.

It soon became clear that the matrix of numbers could be presented pictorially and dynamically, and NTI therefore developed the "Cognitive Vulnerability Map - CVM" as the vehicle for this. An example of this map is shown in figure 1, and it is described in detail in Section Three of this report.

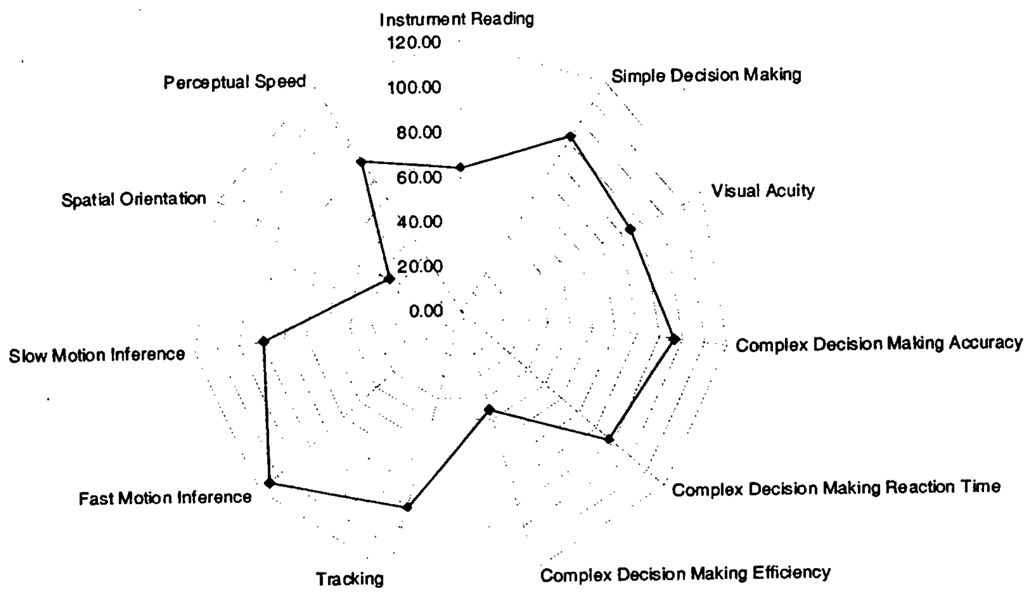


Figure 1. Example of a Cognitive Vulnerability Map (CVM) at 3 Gz

The CVM essentially depicts each of the cognitive processes identified in earlier portions of the program as "spokes" on a wheel. Each spoke therefore identifies the person's measured or estimated level of performance at a given Gz level over time during and after imposition of the G force. In the implemented version of the CVM, normal 1-G performance (as determined from the literature) is considered to be 100%, and is represented by an outer rim of the wheel. As cognitive performance degrades, a marker indicates how far in to the center of the wheel the decrement has progressed. These values, of course, are all taken from the master matrix. Further, the user can enter any G-profile on a second-by-second basis. Thus, onset rates and durations are entered (at present, for up to a two-minute profile -- but this duration can be changed). The G-TOP model then calculates the effect on each cognitive skill over the entire course of the profile. On initiation, these results are presented on the CVM as a dynamic picture, allowing a composite visualization of the changes in a person's cognitive status at any point in the profile. Different profiles can then be entered to see if one can produce minimal cognitive decrement, thus optimizing performance. Of course, the dynamic simulation can be stopped at any point, and the actual matrix values can be inspected.

Summary

The present effort has produced four major innovations that are documented and described in this report. First, a composite cognitive performance test battery was developed (G-PASS) targeted specifically at the critical cognitive processes required by the pilot in the acceleration environment. Second, a technique was developed to permit more objective selection of tests from the battery for specific missions (T-Matrix). Third, an existing technique was adapted to provide estimates of cognitive performance decrement over a wide range of acceleration conditions for which there is no existing literature (G-effective). Finally, a dynamic graphical technique was developed that permits the researcher or operational commander to predict the effects of specific G-profiles and onset rates, and to experiment with different profiles to find one that optimizes cognitive performance (G-TOP). Together, these developments will hopefully identify and guide future research, enhance the development of protective equipment and tactics to maximize performance, and provide meaningful input on cognitive function for systems models such as CART and MANPRINT. Extension of these techniques to other stressor areas may also provide some degree of standardization useful in development of models on the combined effects of stressors on cognitive performance.

SECTION ONE - INTRODUCTION

Centrifuge research has developed many ergonomic advances that assist the human to endure high levels of acceleration force (e.g., anti-g suits and maneuvers, positive pressure breathing) as well as decreasing the time between the approach of an enemy target and the action taken by the pilot (e.g., digital signal processors, head-related transfer functions). Today much is known about the physiological response of the human on the centrifuge and successful methods of improving performance and tolerance have been developed based on this knowledge. While physiological performance research in the high-G environment has produced impressive results, cognitive performance research under increased G forces has proved more problematic. Impressive individual studies have been carried out, but these have not led to generalized models that address predictions of cognitive performance under a variety of acceleration stresses.

The main focus of this SBIR effort was to summarize literature pertaining to critical cognitive processes at various levels of acceleration force, to develop an initial battery of tests for those processes, and to conceptualize a model that dynamically predicts changes in critical flight performance skills as a result of acceleration stress. The goals of this model are: 1) to allow a researcher or operational commander to analyze the effect of acceleration force on the performance of critical cognitive processes, 2) to provide input to elaborate systems models concerning these effects, and 3) to permit optimization of performance in the acceleration environment through use of "what if" scenarios.

The overall effort described below is therefore multi-faceted and multi-targeted. It involves not only an assessment and synthesis of previous work, but a creative effort to incorporate new technologies in order to move beyond "single study" methodology into a more global and predictive orientation. It involves translating the operational terms used by the warrior to the scientific terms used by the cognitive scientist. It involves finding ways to extrapolate from excellent but focused studies to generalized operational conditions. Finally, it involves pulling all of these elements together into a user-friendly technology that will permit immediate visualization and quantification of the cognitive effects of any acceleration profile, and ability to manipulate these cognitive effects. The origins of this effort pre-date the current SBIR, and are described below.

Identifying Critical Cognitive Processes in the Acceleration Environment

Cognitive performance research in the centrifuge at high +Gz currently has produced many individual studies targeting decrements in performance at various acceleration levels (see Appendix A for a review of this complete literature). A few researchers have made an attempt to summarize the various studies to provide an overview of the effects of acceleration force on cognitive performance (e.g. Grether, 1971). None have attempted a synthesis of the data on cognitive performance for the purposes of predicting actual flight performance capability over a broad range of conditions. As a first step toward achieving this goal, one must identify those tasks that are critical to flight performance in a combat situation and locate data associated with the performance of those skills.

The concept of "critical tasks" was adopted in this report for the purposes of studying only those tasks that refer to piloting missions, mission segments, or other behaviors that are critical to survival and mission accomplishment. A conference convened by Drs. Bill Albery and Tammy Chelette of the Armstrong Laboratory (AL/CFBS) (O'Donnell, Cardenas, Eddy, and Shaw, 1996) invited a group of pilot consultants to address the concept of "critical tasks" in the acceleration environment. In this meeting, the pilots identified a list of operational goals that they considered critical that could be affected by acceleration stress. These are presented (in their original terminology) in Table 1.

TABLE 1

CRITICAL PILOT TASKS SUGGESTED IN THE AL/CFBS WORKSHOP

Observe and kill bandit
- Maintain sight
- Maintain advantage
  - Manage energy
  - Achieve shot parameters

Verbal
- Communicate

Motor skills
- Initial missile avoidance
- Detect second missile

Visual
- Acquire target
- Recognize threat
- Evaluate threat
  - Radar lock
  - Missile parameters
  - Bandit range
  - Etc.

Awareness
- Analyze situation
- Check gas, airspeed, floor, etc.

Cognitive
- Develop plan (engage or leave)
- Analyze bandit's maneuver

This original list could then be converted to a summarized list of task requirements that related to the pilot's critical requirements in this environment. This moved the operational language of the pilots one step closer to the kind of language used by the cognitive psychologist. This second-generation list included the following cognitive processes.

1 ***Monitoring tasks under high workload***: The ability of the pilot to monitor such things as altitude and attitude (both head up and head down conditions).

2 ***Collision avoidance***: The ability to monitor the relative motion of an aircraft that is moving in relation to your own aircraft.
3 ***Missile avoidance***: The ability to detect a missile, keep sight of the target, and to continuously track a missile.
4 ***General timing ability***: The ability to respond rapidly to radar lock, missile launch, and pulling an ejection seat handle.
5 ***ILS Landing***: The ability to track and make rapid decisions.
6 ***Unusual attitude recovery***: The ability to maintain manual control and visual motor coordination that could be generalized to other flight conditions.
7 ***Multi-task conditions***: The ability to perform two or more tasks simultaneously.
8 ***Target recognition***: The ability to discriminate targets from friendlies, or to identify friendly forces specifically.
9 ***Formation Operation***: Vectoring, three-dimensional tracking, decision making, collision avoidance, and monitoring.

The final step in this procedure was to determine the actual cognitive processes included in that above operational tasks. Those identified are presented in Table 2 below. As with virtually all previous efforts of this type, terminology is a major problem. In the literature, the same skill or ability is frequently given different names. In addition, some terms that are frequently used (such as "perceptual speed") have never been defined in very precise ways. Therefore, the labels used for cognitive processes in Table 2 are not as important as the descriptions of what they represent for the present effort. In the attempt to keep the processes as flight-relevant as possible, these descriptions reflect the abilities that the pilots were actually talking about when they used terms such as "manage energy", "recognize threat", and "analyze bandit's maneuver". Of course, if a different job or stressor is considered, this list of processes would change.

TABLE 2

COGNITIVE PROCESSES CONSIDERED ESSENTIAL IN THE ACCELERATION ENVIRONMENT

SPATIAL ORIENTATION: Knowledge of one's position in three-dimensional space, and ability to maneuver within that space.

MOTION INFERENCE (SLOW AND FAST): Ability to consider both velocity and time in viewing a moving object.

TRACKING: Visual-motor control to bring or keep a moving object within prescribed spatial limits.

SIMPLE DECISION MAKING: Ability to rapidly and efficiently discriminate among possible, easily discriminated choices -- as in choice reaction time studies.

COMPLEX DECISION MAKING (REACTION TIME, ACCURACY, AND EFFICIENCY): Ability to process multiple sources of information and/or response options fast, correctly, or an optimal combination of the two (efficiently).

VISUAL ACUITY: Deals with both focal and peripheral detection, identification, and interpretation of information.

INSTRUMENT READING: This ability deals with interpretation of easily read instruments of varying complexity.

PERCEPTUAL SPEED: The ability to rapidly input and retain visually presented information (especially spatial information). This ability therefore contains elements of some forms of short-term memory.

Literature Review of Cognitive Processes

As part of this overall effort an extensive review of the available literature on cognitive performance under increased G was carried out. It soon became clear that much of this literature was focused on specific protective equipment or procedures that would confound any attempt to extrapolate the data to the normal environment of the pilot. Therefore, it was decided early to focus on studies that directly addressed the cognitive processes listed above, and these are described in some detail below. For each of the cognitive processes identified above, one or more studies are described, along with selected data from each one. In the interest of completeness, studies that were reviewed but not used in developing the data base are similarly presented in Appendix A.

SPATIAL ORIENTATION

STUDY 1: Albery, W. B. (1990). Spatial disorientation research on the Dynamic Environmental Simulator (DES). AAMRL-SR-90-513.

Subjects were told to estimate their perception of down at 1G while the centrifuge cab was randomly placed at several angles off of vertical (+/-120 degrees, +/-90 degrees, +/-60 degrees and +/-30 degrees). Subjects indicated their perception by manipulating an arrow.

	1Gz	**1.5Gz**	**2Gz**	**2.5Gz**	**3Gz**
Unusual Attitude Recovery, Maintenance	-3	-5.5	0	-2	0.5
Unusual Attitude Recovery, from -30 Degree manipulation	-2.5	-3	2.5	7	9.5
Unusual Attitude Recovery, from -60 Degree manipulation	-2	1	5	6	6
Unusual Attitude Recovery, from +30 Degree manipulation	-1	-3.5	-5.5	-5	-7.5
Unusual Attitude Recovery, from +60 Degree manipulation	1	3.5	-3	-7	-9

STUDY 2: Nethus, T. E., Werchan, P. M., Besch, E. L., Wiegman, J. F., & Shahed, A. R. (1993). Comparative effects of +Gz acceleration and maximal anaerobic exercise on cognitive

task performance in subjects exposed to various breathing gas mixtures. Abstract, *Aviation, Space, and Environmental Medicine, 64*(5), 422.

The Manikin orientation task was performed at various acceleration levels. Response time and error rate were averaged as the dependent variable for the Manikin Task.

	PreGz	sacm4-7	Post
Manikin Error rate, 14 FIO2 (%)	0.125	0.175	0.23
Manikin Error rate, 16 FIO2 (%)	0.12	0.1	0.18
Manikin Error rate, 18 FIO2 (%)	0.12	0.125	0.18
Manikin Error rate, 20 FIO2 (%)	0.1	0.16	0.125
Manikin Error rate, 60 FIO2 (%)	0.08	0.125	0.225

MOTION INFERENCE (SLOW AND FAST)

Repperger, D. W., Frazier, J. W., Popper, S., & Goodyear, C. (1990). Attention anomalies as measured by time estimation under G stress. Biodynamics and Bioengineering Division, Wright-Patterson Air Force Base, Ohio.

The time estimation task involved a noncounting procedure. This task required the subject to observe on the video display a target going from left to right across the screen for a short period of time (8 or 16 seconds). The target disappeared for an invisible portion of the screen and then the subject had to estimate how long a time period would be required for the target to continue moving at that velocity to reach a marker near the right edge of the CRT.

	1Gz	3Gz	5Gz
Motion Inference, 2Sec. Task	0.6	0.6	0.4
Motion Inference, 8Sec. Task	0.56	0.4	0.96
Motion Inference, 16Sec. Task	1.28	1.92	2.24

TRACKING

Rogers, D. B., Ashare, A. B., Smiles, K. A., Frazier, J. W., Skowronski, V. D., & Holden, F. M. (1973). *Effect of modifies seat angle on air-to-air weapon system performance under high acceleration.* Memorandum-AMRL-TR-73-5. Wright-Patterson AFB, OH: AF Aerospace Medical Research Laboratory.

In this study, the gunsight provided the primary visual cues for an air-to-air tracking task. The sight and target were computer generated and electronically displayed to the subject with appropriate scaling for dynamic fidelity. The sight was located in a standard position and rotated back with the seat. The sight display provided a simulation of lead angle computation as is necessary for accurate performance measurement.

	1Gz	2Gz	3Gz	4Gz	5Gz	6Gz	7Gz	8Gz
Tracking, % Decrement	100	97	90	85	80	65	50	23

COMPLEX DECISION MAKING REACTION TIME, ACCURACY, AND EFFICIENCY

Cochran, L. B. (1953). Studies on the ease with which pilots can grasp and pull the ejection seat face curtain handles. *Journal of Aviation Medicine, 24*, 23-28.

On test runs, the centrifuge accelerated to peak G with the centrifuge chamber in darkness. When the desired rate of acceleration was attained, the chamber lights were turned on, as a signal for the pilot to "bail out." He then attempted to elevate his arms, grasp the face curtain handles and pull them downward, thus simulating the procedure necessary to actuate the ejection seat firing mechanism. When the face curtain was fully extended, a microswitch was triggered energizing a marker relay. A timing mechanism recorded the interval between the signal to "bail out" and "successful ejection." This interval was recorded as reaction time. Accuracy was determined by whether the subject completed the task or not. "Efficiency" was determined by adapting the throughput measure employed by Thorne and colleagues (1985). Throughput is a measure that accounts for a speed-accuracy tradeoff. To calculate throughput, the percent accuracy was divided by the average response time.

	1Gz	**2Gz**	**3Gz**	**4Gz**	**5Gz**	**6Gz**
D-Ring, % Accuracy	100	95	93	90	100	90
D-Ring, Reaction Time(Sec.)	1.6	1.8	2.1	3.5	3	2.8
D-Ring Throughput	62.5	52.78	44.29	25.71	33.33	32.14
Face Curtain, % Accuracy	100	100	100	100	100	90
Face Curtain, Reaction Time(Sec.)	0:5	1.5	2.5	3.9	4.1	4
Face Curtain Throughput	200	66.67	40	25.64	24.39	22.5

VISUAL ACUITY

The variable "visual acuity" is made up of a variety of measurement methods. The majority of data was collected while testing focal acuity with one study including a method for measuring peripheral acuity.

STUDY 1: White, W. J. (1960). Variations in absolute visual thresholds during acceleration stress. ASD-TR-60-34 (DTIC-AD-243612).

The test procedure for measuring thresholds during the experiment was a modification of the psychological method of limits. In this way, the luminance of the test flash is made to oscillate around the threshold of the subject during the course of an experimental run. The amplitude of these oscillations is a measure of the difference limen for luminance at the absolute threshold. Experimental runs lasted one minute-fifteen seconds and were spaced 2 minutes apart. During a run, approximately 14 alternate ascending and descending threshold determinations were made. In some runs, especially those at maximum acceleration, the number of determinations was somewhat less than this, but never less than 8.

	1Gz	**2Gz**	**3Gz**	**4Gz**
Absolute Threshold (Foveal)	6.66	6.76	6.92	7.19
Absolute Threshold (Peripheral)	3.35	3.49	3.79	3.92

STUDY 2: Chambers. R. M., & Hitchcock, L. (1963). *Effects of acceleration on pilot performance*, NADC-M-6110, DTIC-AD-408686, Warminster, PA.

In this task, visual brightness discrimination was studied at four levels of background luminance, at four levels of positive acceleration, and at five levels of transverse acceleration. For this study, a stimulus display generator was mounted in the gondola. This generator presented a circular test patch against a diffuse background. The display was viewed monocularly through an aperture which was 17 ½ inches from the eye. The visual angles subtended by the circular test patch and its background were 1 degree and 8 minutes, and 8 degrees and 4 minutes, respectively. A response button, provided to the subject, was used to indicate the appearance or disappearance of the test patch. Approximately 15 responses were made during the peak G of each run. Determinations were made at each G level with background luminance of .03, .29, 2.9, and 31.2 foot-lamberts.

	1Gz	**2Gz**	**3Gz**	**5Gz**
Contrast Sensitivity	9.4	10.9	11.5	15.6

STUDY 3: White, W. J. (1962). Quantitative instrument reading as a function of illumination and gravitational stress. *Journal of Engineering Psychology, 3*, 127-133.

The Wright Air Development Center human centrifuge was used in this study. Instrument reading performance was measured by using the apparatus and procedures developed by Chalmers, Goldstein, and Kappauf (1950) as a standardized method for studies of dial reading behavior. The reading material consisted of a panel of twelve dials. The dials were scaled from 0 to 100 over the full circumference, and one type was graduated by fives while the other was graduated in units. The panel was located directly ahead of the subject and at 28 inches from the eye. At the highest brightness level the white portion of the dial was 42 millilamberts. The background of the dials and panels was matte black and less than one tenth as bright as the white instrument markings. Subjects were instructed to read both types of instrument dials to the nearest unit. Subjects were not informed of the acceleration levels they were about to be exposed to nor where they given feedback on their performance. Subjects were exposed to acceleration levels ranging from 1 to 4 Gz. Subjects wore CSU-3/P anti-G suits.

	1Gz	**2Gz**	**3Gz**	**4Gz**
Contrast Sensitivity	18	18	38	44

STUDY 4: Frankenhauser, M. (1958). Effects of prolonged gravitational stress on performance. *Acta Psychologica, 14*, 92-108.

A modification of a clinical procedure for measuring visual acuity was adopted. A photographic copy of one of Bostrom's test-figures, reduced to 0.7 X 0.7 millimeters, was used and the subject had to report verbally the position of the gap (left, right, up, down). The figure was presented at a distance of one meter. The position of the gap was varied in a predetermined, random order. The subject was instructed to lean his head against the back of his chair. The subject was allowed to work at his own speed. As soon as he had responded to one stimulus, the next was exposed. He was instructed to guess when in doubt.

	1Gz	3Gz	1Gz
Percent Error of visual acuity	12.68	29.01	10.11

SIMPLE DECISION MAKING

STUDY 1: McCloskey, K., Albery, W. B., Zehner, G., Bolia, S. D., Hundt, T. H., Martin, E. J., & Blackwell, S. (1992). NASP re-entry profile: Effects of low-level +Gz on reaction time, keypad entry, and reach error. (DTIC-AL-TR-1992-0130). Wright-Patterson Air Force Base, Ohio.

A choice reaction time task required subjects to monitor the forward-mounted visual display screen for the occurrence of lighted circles. There were four circles presented, and the number and location of the circles which were lighted at any given time were randomized. Either one, two, or three circles could be lighted during any trial. Subjects were then required to depress the corresponding number and location of buttons on a four-button response pad located on the center-mounted console. Subjects used the first two fingers of each hand to respond. See Task 2 for data. In addition, a six-digit entry number appeared on the visual display screen, and subjects were required to enter that number on the response keypad, and then press the pound-sign key (#) to indicate closure for those trials. The keypad entry response device was a standard push-button pad taken from a telephone. Each subject used their dominant hand. There were 30 single trials per session. Each single trial consisted of the presentation of a totally random six-digit number, the number entered on the keypad, and a pound-sign keystroke. Errors included taking more than 6000 msec to complete the trial, or entering a wrong number during keypad entry. There was no allowance to correct or erase an incorrect keystroke. The six-digit numbers were presented randomly between 350 and 750 msec after the pound-sign keystroke to once again control for response rhythm and prediction of stimulus occurrence.

2Gz	Baseline	0 Min	8 Min	16 Min	24 Min	32 Min.
Reaction Time RT	469	449	439	444	451	450
Reaction Time Error	1.4	1.8	1.9	2.3	2.2	2.1
2Gz		**2.5Min.**	**10.5Min**	**18.5Min**	**26.5Min**	**34.5Min**
Keypad Entry RT	3514	3944	3724	3714	3754	3634
Keypad Entry Error	2.6	4.4	3.6	2.9	3.4	4.2

STUDY 2: Frankenhaeuser, M. (1949). Effects of prolonged gravitational stress. *Acta Psychologica, 14*, 92-108.

Red, green and white signals were used as stimuli. The subject had two signal switches, one in each hand, which required a movement of about one millimeter for signaling. He was instructed to respond to the stimuli in the following manner:

1 Red light - left hand switch
2 Green light - right hand switch
3 Red and white light simultaneously - right hand switch
4 Green and white light simultaneously - left hand switch
5 Red and green light simultaneously - no response

This is thus a five-choice task, involving reversals and inhibition of response in addition to the basic 2-choice task.

	1Gz	3Gz	3Gz	Post
Time in Sec.	0.724	0.782	0.75	0.729

INSTRUMENT READING

Warrick, M. J., & Lund, D. W. (1946). *Effect of moderate positive acceleration (G) on the ability to read aircraft instrument dials.* Memorandum-TSEAA-694-10. Wright-Patterson AFB, OH.

An instrument reading test was assembled containing eight rows of the nine common aircraft instrument dials used in the AFF classification test, "Tables and Dial Reading Test, CP-622-A." The dials were mounted on a 16- by 18-inch piece of Bristol board, four rows numbered 1 through 4 on one side and four rows numbered 5 through 8 on the reverse side. Each row presented similar instruments in the same order but with different readings. Immediately above each dial a number was presented which corresponded to the reading. Some were markedly different from the reading. Thus the test was essentially a true - false test of whether or not the dial read was the same as the number above it. This number was intentionally drawn quite large in hopes that it would remain clearly readable under conditions of moderate G. The test items were selected with care to equalize the difficulty of reading the comparable instruments of each row and at the same time, avoid a systematic pattern of right and wrong items. If the answer was right, it was as nearly correct as the authors could read the dials under ideal conditions. If the answer was wrong, it was an error by at least one scale division.

	1.5Gz	3Gz
R-W scores	12.65	10.56
Errors	3.47	4.71

PERCEPTUAL SPEED

STUDY 1: Frankenhauser, M. (1958). Effect of prolonged acceleration on performance. *Acta Psychologica, 14*, 92-108.

The identical Forms Test described by Thurstone (1943) was modified for use in the centrifuge. Each test item consists of a stimulus figure and five similar test figures (numbered 1 to 5) one of which is identical to the stimulus figure. The subject's task is to identify the test figure which is identical to the stimulus figure and report its number verbally. The test includes 60 items which were presented to the subject on cards of 10 items each. 40 of these items were presented during centrifugation.

	1Gz	3Gz	Post
Reaction Time in Sec for Perceptual speed	160.67	289.33	127.67

STUDY 2: Comrey, A. L., Canfield, A. A., Wilson, R. C., & Zimmermann, W. S. (1951). The effect of increased positive radial acceleration upon perceptual speed ability. *Journal of Aviation Medicine, 22*, 60-69.

Subjects were shown 15 items each with a center stimulus (test stimulus) and four surrounding choice stimuli located above, below, to the left, and to the right of the test stimulus. The subjects was to respond "up," "down," "left," of "right," depending upon where the subject thought the item identical with the center figure was located. The dependent measure was the number of correct responses in a 15 second period for six trials.

	1Gz	2.5Gz	4Gz
T-score equivalent for raw number correct	52.59	52.32	47.62

The above studies formed the essential data base from which overall estimates of the effects of acceleration on these cognitive functions were derived. It is important to note that many other studies were surveyed (see Appendix A) before determining that the studies listed above represented the best foundation presently available for such estimates. However, for various reasons the data reported in the other studies could not easily be interpreted within the context of the present goals. For example, an excellent study by Morrison, Forster, Hitchcock, Barba, Santarelli, and Scerbo (1994) had subjects perform the NASA Multi-attribute Task Battery, which is made up of a compensatory tracking task, a system monitoring task, and a resource management task. This would have provided good data for the present purpose. However, the subjects in the study wore either a Standard Anti-G suit with Combat Edge or Eagle suit (composite data was reported because there was no significant differences) which may have possibly skewed the results. Also, an average value was reported for +3-5Gz rendering differentiation between the effect of +3Gz from +5Gz impossible.

Although the above studies are believed to be the best currently available for the data base, their limitations must be recognized. Many are old studies carried out with equipment that is considered primitive by today's standards. There is little standardization of terminology in terms of what cognitive functions are being studied, and reporting of procedures and statistics is sometime spotty. As a result, the actual data base itself must be considered a "work in progress". Hopefully, as new studies are carried out, these original data can either be validated or, if necessary, modified. In any case, the overall methodology developed under this program is flexible enough to permit continual development.

Development of Normalized Measures

The next stage of this effort was to create normalized performance curves for each cognitive process. Given the variation in how dependent measures were reported, it became necessary to design a formula that would allow for the data at each +Gz level to be compared to its +1Gz baseline. The following general equation was used to convert reported decrements at each G level to a "percent decrement from baseline"

$$100-(((nGz\ data-1Gz\ data)/1Gz\ data)*100)$$

Although some modifications of this basic formula were necessary in a few cases (due to the way the data were reported) the technique essentially yielded normalized measures over all of the studies described above. These normalized values for the selected studies are presented in Table 3 below. In this Table, the values at 1Gz are converted to 100 for each of the studies, and the changes at higher Gz levels are expresses as a form of "percentage decrement."

TABLE 3

NORMALIZED DATA USED IN THE DATA BASE

Reference	*Dependent Measure*	*1Gz*	*2Gz*	*3Gz*	*4Gz*	*5Gz*	*6Gz*	*7Gz*	*8Gz*	*9Gz*
Dial Reading (Instrument Reading)										
Warrick & Lund, 1946	Errors	100.00		64.27						
Choice Reaction Time (Simple Decision Making)										
McCloskey et al., 1992	Reaction Time (msec)	100.00	87.50							
Frankenhauser, 1958	Reaction Time (sec)	100.00		91.99						
Visual Acuity										
White. 1960	Absolute Threshold (Peripheral)	100.00	95.82	86.87	82.99					
	Absolute Threshold (Focal)	100.00	98.50	96.10	92.04					
Chambers & Hitchcock,1963	Contrast Sensitivity	100.00	84.04	77.66		34.04				
White, 1962	Contrast Sensitivity	100	100	80	74					
Frankenhauser, 1958	Percent Error of visual acuity	100		83.66						
Decision Making (Complex Decision Making)										
Cochran, 1953	Average Percent Accuracy	100.00	97.50	96.50	95.00	100.00	90.00			
	Average Reaction Time	100.00	94.00	87.50	73.50	75.00	76.50			
	Average Throughput	100	58.89	45.43	26.98	32.76	31.34			
Tracking										
Rogers et al., 1973	% Accuracy	100	97	90	85	80	65	50	23	
Motion Inference										
Repperger et al., 1990	Motion Inference, Slow Velocity	100		89.29		26.79				
	Motion Inference, Fast Velocity	100		114.29		80.95				
Spatial Orientation										
Albery, 1990	+30 Degree manipulation	100.00	55.00	35.00						
Nethus et al., 1993	Manikin Error rate, 14 FIO2 (%)	100.00				60.00				
Perceptual Speed										
Comrey et al., 1951	T-score equiv. for raw number correct	100.00	98.61		90.55					
Frankenhauser, 1958	Reaction Time (sec)	100.00		80.10						

The value of this normalization process should not be underestimated. Impressive differences in the effect of Gz forces on the different cognitive processes immediately become evident. From an inspection of the data in Table 3. This is apparent if the data are plotted as is done in figure 2.

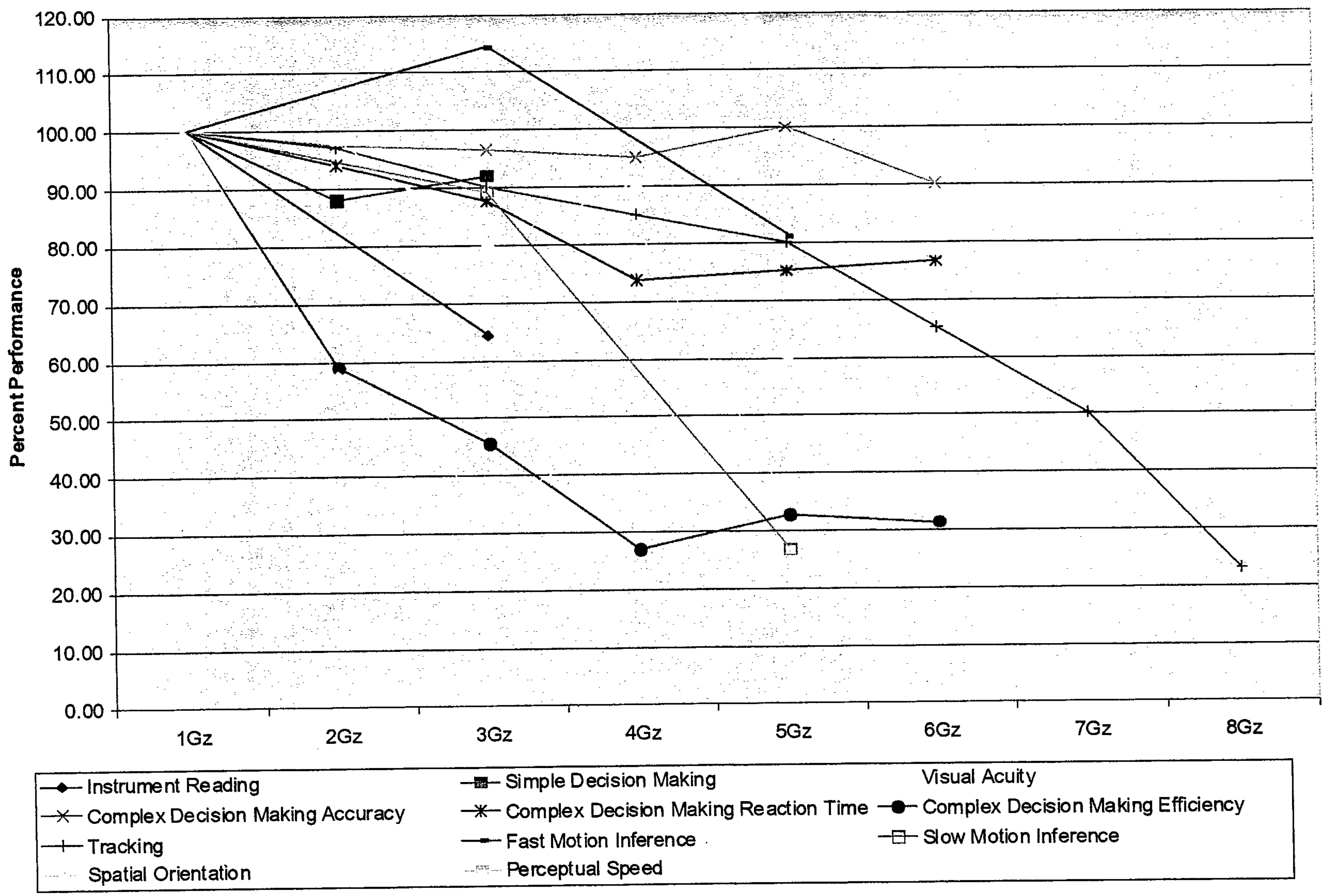


Figure 2: Cumulative Performance Data From Past Literature

SECTION TWO

DEVELOPMENT OF THE G-PERFORMANCE ASSESSMENT SIMULATION SYSTEM (G-PASS)

Rationale for Test Selection

The literature review cited above revealed a need to develop a more standardized and theoretically complete battery of tests that would be appropriate for use in the centrifuge. Identification of such tests is made more difficult because of the limitations of time and equipment introduced in the acceleration environment. Exposure to increased G must necessarily be limited, and test equipment must be designed to withstand extreme stresses. Fortunately, NTI has specialized in the development of performance tests, and in the course of more than 17 years, has investigated a vast number of such procedures. This history provided the initial foundation for assembling a specialized test battery.

Above this, however, the definition of critical operational flying tasks described in Section One of this report was used as the starting point in considering tests. Following the content of current cognitive models, this operational orientation was used to define the general cognitive processes that should be covered by the battery (see Table 2 above). Finally, a set of performance measures was selected that probed these cognitive processes. Essentially, then, these measures were selected because of their content and construct validity, based on previous research and on practicality in the centrifuge environment. This process is summarized in figure 3 below.

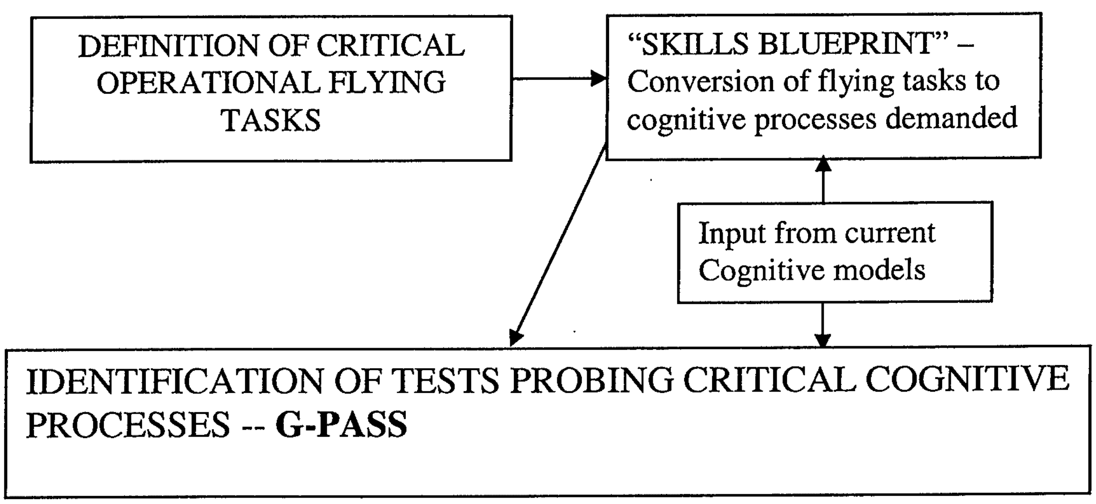


Figure 3. Process leading up to the development of G-PASS

G-PASS Tests

The final battery that was developed consists of two major types of test. In one type, the tests are designed to be presented either in the centrifuge or outside of it. These "stand-alone" tests are not typically embedded into a flight simulation. The second type involves procedures that are designed to be administered in the context of a flight simulation -- they are embedded within the simulation. Both types can be administered before, during, or after exposure to increased G forces. The following is a short description of each of the tests in the G-PASS test battery. A full user's manual detailing specific procedures, experimenter options, and analysis recommendations is supplied as Appendix B of this report.

Test 1: Perception of Relative Motion.

One of the more important skills required of the pilot is to be generally aware of the relative position of one or more other aircraft with respect to his or her "own ship." This test particularly targets the critical tasks of *collision avoidance* and *formation operation.*

The task chosen to probe the perception of relative motion is a "join-up task" where the goal is clearly defined and the maneuvering options can be mathematically described. This task is essentially a two dimensional tracking task, although it differs from traditional tracking tasks in several ways. The subject's sole task is to regulate the apparent direction and speed of closure of two objects. The objects consist of a fighter aircraft icon and a "tanker" aircraft icon. The tanker begins the trial in the upper segment of the screen, and is very small. The fighter aircraft represents "own ship", and is located at the lower center of the screen. The task is to "fly" the fighter to the tanker and join. By manipulating the joystick and throttle, the subject sees the tanker appear to move closer to the fighter. The "boom" of the tanker is the targeted point of contact, and errors or inefficiency in making the "link up" are the dependent measures.

Test 2: Precision Timing Task.

The essential skill demand in this category is that the pilot visually monitors a changing situation and decides at some critically identified point to initiate a motor action. The piloting demands that require this skill involve precision timing (general timing ability) especially visually directed precision timing. The critical task probed by this test is *general timing ability* and influences all decision making actions including air-to-air and air-to-ground situations, flare decisions, formation flight, and decisions to abort landing and other activities.

In this task the individual must monitor what appears to be a rapidly moving target for a brief period of time. At some point in the path of the target's motion, an indicator appears in the target's path. The subject's task is to press a button on the stick when the indicator reaches that point. The distance and/or time error of the subject in precisely stopping the target at the right time constitutes the basic measurement parameter of this task.

Test 3: Motion Inference (Time/Velocity Estimation).

In the combat situation, there are instances where the individual must perceive and register the motion of an enemy or another object, then must turn away from the direct visual perception of the object briefly. However, the object's motion must still be processed in order to know where it should be when it is again attended to. In such cases, the individual must infer motion based on a previous perception of motion. This must frequently be done while other tasks are being performed. Clearly, this places a considerable burden on working memory, especially as it interacts with short-term memory. Response selection and timing are also critical in this case. Critical tasks targeted by this test include *collision avoidance, missile avoidance, general timing ability, multitasking, and formation operations.*

This test utilizes a moving target that, at some designated point, disappears. The subject's task is to estimate when the object, moving at either a constant rate or an accelerated/decelerated rate will "hit a target." To stop the subject from counting or developing strategies to estimate the time, a secondary task is introduced in which the subject must determine whether a vowel was present in a string of 4 letters after the disappearance of the moving target. After responding to the secondary task, subjects respond when they estimate the moving target has reached the stopping point.

Test 4: Pitch/Roll Capture.

A critical survival skill in air-to-air combat involves the ability to rapidly position the aircraft in order to move a "bandit" into a specific location relative to your aircraft's aiming devices. Essentially, the pilot must recognize the bandit's relative position, and then must make a rapid correction in his or her own position and attitude in order to gain the proper aiming advantage. This rapid maneuver might be in the vertical relative to the aircraft ("pitch capture"), or laterally ("roll capture"). These terms refer to the required control input, pitch or roll, which will bring the bandit into the desired position. Delays or errors in doing so will obviously have an impact on the outcome of the air engagement. Critical tasks targeted by this test include *unusual attitude recovery* and *formation operation.*

A static, medium-fidelity simulation of the actual pitch and/or roll capture as it would be carried out in a fighter aircraft is used for this task. The subject sees a static, front cockpit simulation that simulates an elementary cockpit view, with an out-the-window blue sky. At some random time during the trail, a target will appear in one of several locations around the cockpit field of view.

The essential element of this task is that the subject must detect the presence of an "enemy" aircraft, which may appear in any of the positions. The subject must bring the enemy aircraft into the gunsight as rapidly as possible, using a standard sequence of control behaviors. This sequence consists, first of all, in a "roll" maneuver (tracking either to the right or the left of the screen). The goal of this roll maneuver is to bring the enemy aircraft in between two vertical lines representing the center of the cockpit. The time taken to bring the enemy aircraft within the vertical lines is the major dependent measure for this aspect of the test.

The second performance requirement in this test is that the subject must "pitch" the display forward a precise amount in order to bring the enemy aircraft finally within the gunsight. Again, the amount of time taken to complete this separate maneuver constitutes a major dependent measure of this task. As soon as the subject achieves the desired outcome, within pre-established limits, this task ends.

Test 5: Peripheral Vision.

The ability to detect enemy aircraft, monitor various cockpit signals, maintain sight of a missile, and many other functions of a pilot are highly dependent on one's ability to use peripheral vision. For this reason, it is crucial to be able to test for the ability to recognize signals that are directly monitored while also testing for the ability to detect signals during other tasks such as flight simulations. This test probes the critical tasks of *missile avoidance* and *target recognition* and possibly *monitoring under high task load* and *multitasking*.

In this procedure, the experimenter can present various kinds of cockpit information at any point in the visual field. Specifically, although primary interest is in peripheral information processing, focal processing may sometimes be of interest. Different kinds of information can be presented (e.g., round or strip displays). Duration of stimulus presentation, as well as size and color of the stimulus is controlled by the experimenter. Depending on the experimental design, the test may be presented in a stand-alone mode, or may be embedded into a flight simulation or into one or more additional tasks. The dependent variables of interest in this task may include whether or not the subject detects the stimulus, whether movement of various kinds was detected, and the accuracy and latency of such detection.

Test 6: Rapid Decision Making.

One of the skills considered essential to the pilot's ability is his or her decision-making capacity. It is generally believed that the ability to rapidly attend to a stimulus input, analyze it in relation to established rules and learned relationships, and then to choose between two or more alternatives through a motor action is crucial to success in the flight environment. Obviously, this function can be inferred from the flight simulation measures, but a more focused and experimentally manipulable measure was desirable. Pilot consultants and government personnel have suggested that the radar warning receiver (RWR) display might provide an appropriate stimulus element for this type of function. In this display, a radar threat accompanies the appearance of the stimulus on the scope. The subject must rapidly assess the nature of the threat, as well as its severity, and decide on an appropriate response. The test therefore assesses several aspects of working memory as well as decision making ability and reaction timing. The critical tasks related to flight involve *general timing ability* and *monitoring under high workload.*

Test 7: Basic Flying Skills.

It has been argued that "macro-cognitive" elements - those that involve complex, higher-order cognitive processes cannot be captured by combinations of simpler processes such as those tapped by other tests in G-PASS. These involve elements such as decision making, uncertainty management, and situation awareness. Therefore, to approach these issues in the present context they are embedded into the complex real-world tasks of flight. This test procedure provides a realistic aero model of the F-16 aircraft, and a navigation mission scenario. The subject will "fly" that mission, either under varying G forces, or off-line after G exposure. Scoring techniques involve standard measures of altitude, speed, and navigation errors. The designed scenario allows for the inclusion of any of the following tests during the basic flying task.

Test 8: Gunsight Tracking.

Tracking is a critical task that is inherent in many other operations that are vital to flight performance. This task probes *collision avoidance, missile avoidance, ILS landing, and formation operations.*

This task requires the pilot to track a target, which is "flying" a predetermined path. The task is able to be carried out in either an open loop or closed loop manner, or it can be presented off-line. The obvious goal is to measure the pilot's visual-motor control ability, as represented in working memory. The various metrics to be obtained will serve as direct inputs into any simulation utilizing a cognitive model, or any systems model that might be utilized. As such, the metrics for this test constitute one of the most directly applicable inputs to various types of models (i.e., any decrement in the subjects tracking ability should directly reflect the individual's likely response in the real world, without intervening assumptions).

Test 9: The Blanking Test for Assessing Situation Awareness.

It is desirable to provide some measure of the situation awareness of the subject. Among the techniques designed to probe situation awareness, the blanking technique (SAGAT) described by Dr. Mica Endsley is arguably the most widely used, although it is not without its critics. In this approach, the ongoing simulation is stopped or "blanked" unexpectedly, and the subject is to ask a question concerning some aspect of the situation at the moment of blanking. The general concept is that if the question probes a relevant aspect of the situation at the time, and the subject's answer will indicate his or her level of global situation awareness. Several kinds of questions can be asked - at the simplest level, the question simply asks about an environmental condition at the time of the blanking (e.g., "What is your altitude?"). More complex questions might involve anticipating the actions of an enemy or friendly aircraft, or might require the pilot to manipulate two or more pieces of information in order to answer the question. The software for this test does not specify what questions should be asked in any particular application, since these will be unique to the experimental design. Critical cognitive processes targeted by this test include short-term memory, situation awareness, and spatial orientation. Critical task involves *monitoring under high workload.*

Test 10: Unusual Attitude Recovery.

The speed and appropriateness of a pilot's ability to regain straight and level flight when, for whatever reason, the aircraft gets into an attitude that is not desirable or appropriate appears to probe the immediacy of his or her perception of the situation, integration of this situation with immediate past situations and goals, and implementation of well-learned "schemas" or "scripts" for responding to the unusual situation. This test probes *unusual attitude recovery* as well as *monitoring under high workload* in a sense that if attitude and altitude are not monitored, recovery will moderate. The test consists of an unusual attitude that may appear as soon as the cockpit scene re-appears after a "blanking" situation awareness question, as described in Test 9 above. In all cases, the aircraft will be in an altitude which, 1) could not have been anticipated by the pilot, and 2) represents a dangerous condition of the aircraft. The required response will be to recover from the unusual attitude as quickly as possible. Measures of speed and appropriate response will be collected.

Test 11: Short-Term Memory.

The purpose of this test is to probe the general efficiency of "short-term" memory processes and their susceptibility to disruption by acceleration forces. The term short-term memory is used here in a fairly narrow sense in that the subject must take information in, hold it in memory for some period of time, and then act on it. The test is a straightforward test in which the subject is instructed to carry out the action in the future, and an intervening task is presented before the action is to be taken. Interest is in whether the subject remembers to carry out the task, and whether the information was distorted during the intervening time. The researcher has the capability of varying both the time interval in which the information must be stored and the type of information processing that will be required.

Test 12: Visual Monitoring.

A divided attention paradigm is used to probe working memory functions in the context of the centrifuge. The subject is required to monitor systems visually while performing normal flight functions. The basic concept is that any of four selected display devices will indicate a degraded condition in some system. The subject must first detect the degraded conditions and take an appropriate remedial action (switch activation or verbal response). The goal is not to make the visual detection task a threshold detection task - the displays are relatively easy to detect if scanned properly. This test should therefore probe the "automatic" functions of working memory. Essentially, the test is a visual detection task, although some simple decision processes may be employed. The researcher will be permitted to introduce the detection task at any point in the mission, thereby determining the background workload level against which the task must be performed. This test strongly probes *monitoring under high workload.*

The T-MATRIX Concept

In the past, virtually all performance test implementation has been theoretically uni-dimensional. Researchers selected a test because it appeared to primarily probe a given skill. At the same time, everyone was aware that no test probes only one skill or cognitive process. Even simple tests require some degree of various cognitive processes. In other words, a complete description of what a given test measures would involve developing a vector containing all of the processes probed by the test, and the degree to which each is critical to successful performance on the test. However, to this point there has not been a technique applied in the performance assessment field to quantify these various other contributors to the final performance.

In the course of developing the G-PASS test battery, NTI became aware of a technique used by the Educational Testing Service (ETS) for selecting items in an educational test (DiBello, Stout, and Roussos, 1995). Essentially, the technique (termed the Q-Matrix) attempts to derive vector weights for the test items that describe how much the items depend on specific knowledge or attributes within a skill. This is done by creating a matrix listing attributes in one dimension and test items or questions in the other. Expert opinion is then used to determine whether a test item does or does not require a given attribute. Boolean algebra is then used to generate vector scores for each item, based on the degree to which each test item probes the attributes that the entire test is purported to measure.

It appeared that this approach might be adapted to generate estimates of the degree to which a given G-PASS test probes each cognitive process. In this adaptation (which we now term the T-Matrix, since it deals with tests rather than with questions) the cognitive processes critical for successful flight performance are listed in one dimension of the matrix, and the G-PASS tests are listed in the other. A panel of subject matter experts then determines "to what degree each G-PASS test probes each critical cognitive process". Data-based "ratings" (from 0 to 9) of the amount each tests probes each cognitive process are entered into the cells of the matrix. From these values, an algebraic vector is developed for each G-PASS test. If one knows the degree to which each cognitive skill is required by a given job (e.g., fighter pilot), an optimization algorithm can then be applied to select the minimum number of G-PASS tests required to assess that job.

In the present demonstration of this technique, a group of cognitive scientists provided draft estimations of the degree to which each G-PASS test probes each of the designated cognitive processes. This was done on a scale from 0 (test does not probe this skill) to 9 (test primarily probes this skill). These ratings are presented in Table 4. It should be noted that the ratings in Table 4 are for demonstration purposes only. To develop the final T-Matrix, the procedure should be conducted again with pilots and other government personnel joining the cognitive scientists.

To further illustrate how this approach would be applied to an actual military task, estimates were also obtained for how critical each of the cognitive processes is to a pop-up bomb maneuver. In this scenario, the pilot must come in low, rapidly ascend to a moderately high altitude, then invert and dive toward to target, dropping the bomb at the appropriate time. Again, the estimates shown in Table 4 are for demonstration only. In practice, these estimates would ideally come from subject matter experts (fighter pilots), and would represent the vector describing the cognitive skills necessary for this maneuver. To determine an optimal set of tests from the G-PASS battery, an optimization algorithm would be applied that would reveal the best and most economical sub-set of tests for this application.

Of course, there is any number of possible ways to optimize the test selection, ranging from very simplistic to very complex mathematical approaches. Once the T-Matrix is developed, along with estimates of the job or mission requirements, the researcher is free to select the best algorithm for his or her specific purpose.

TABLE 4

DEMONSTRATION OF T-MATRIX ESTIMATES FOR THE G-PASS TESTS

	Instrument Reading	Simple Decision Making	Visual Acuity	Complex Decision Making Accuracy	Complex Decision Making RT	Complex Decision Making Efficiency	Tracking	Slow Motion Inference	Fast Motion Inference	Spatial Orientation	Perceptual Speed
Pop-up Bomb Maneuver	**9**	**5**	**6**	**7**	**8**	**7**	**9**	**2**	**9**	**9**	**6**
Perception ofRelative Motion	0	1	0	0	0	0	4	3	4	7	6
Precision Tirning	0	4	0	0	0	0	8	6	5	0	9
Motion Inference	0	6	0	0	0	0	4	9	9	0	7
Pitch/Roll Capture	0	3	0	0	0	0	8	2	2	3	2
Peripheral Processing	5	6	9	0	0	0	0	0	0	0	7
Decision Making	0	2	4	9	9	9	0	1	3	0	1
Basic Flying Skills	7	3	0	0	0	0	2	0	0	4	0
Gunsight Tracking	0	1	4	0	0	0	9	5	7	0	4
Situation Awareness	6	1	5	5	2	2	3	2	2	8	0
Unusual Attitude Recovery	9	3	0	6	3	8	0	0	0	9	2
Short Term Memory w/ Distraction	0	4	0	3	1	3	0	0	0	3	0
Visual Monitoring	4	1	6	0	0	0	6	0	0	0	3

An example of a relatively simplistic approach to optimization might be to multiply each rating given to each cognitive process for the mission by each rating shown in the cells of Table 4. For instance, "instrument reading" is given a "9" in Table 4, and the "peripheral processing" G-PASS test is estimated to be involved in instrument reading with a rating of "5". Multiplying these two gives that test a composite value of "45", which then represents the combined "skill-test" match up. The results of this multiplicative matrix are shown in Table 5. The next step is to sum all the values for each test to yield the composite contribution of that test to assessing the cognitive processes required by that mission or job. The result of this summation is shown in Table 6.

That Table reveals a good spread of contributions to the pop-up maneuver by the various G-PASS tests, ranging from 311 to 97. If these were actual values, one would select "Unusual Attitude Recovery" (ranked 1), followed by "Situation Awareness" (ranked 2) and "Decision Making" (ranked 3) as a basic test battery. If more tests could be used, one might want to include "Gunsight Tracking", and perhaps "Motion Inference".

It can be seen that the T-Matrix approach allows a quantified rationale for test selection. Of course, there is still a large measure of subjective judgment involved, but this is done at a finer level than past test selection procedures, and provides an audit trail so that the procedures can be evaluated.

TABLE 5

MULTIPLICATIVE T-MATRIX OPTIMIZATION DEMONSTRATION

Pop-up Bomb Maneuver	Instrument Reading	Simple Decision Making	Visual Acuity	Complex Decision Making Accuracy	Complex Decision Making RT	Complex Decision Making Efficiency	Tracking	Slow Motion Inference	Fast Motion Inference	Spatial Orientation	Perceptual Speed
	9	5	6	7	8	7	9	2	9	9	6
Perception o Relative Motion	0	5*1=5	0	0	0	0	9*4=36	2*3=6	9*4=36	9*7=63	6*6=36
Precision Tining	0	5*4=20	0	0	0	0	9*8=72	2*6=12	9*5=45	0	6*9=54
Motion Inference	0	5*6=30	0	0	0	0	9*4=36	2*9=18	9*9=81	0	6*7=42
Pitch/Roll Capture	0	5*3=15	0	0	0	0	9*8=72	2*2=4	9*2=18	9*3=27	6*2=12
Peripheral Pocessing	9*5=45	5*6=30	6*9=54	0	0	0	0	0	0.	0	6*7=42
Decision Maing	0	5*2=10	6*4=24	7*9=63	8*9=72	7*9=63	0	2*1=2	9*3=27	0	6*1=6
Basic FlyingSkills	9*7=63	5*3=15	0	0	0	0	9*2=18	0	0	9*4=36	0
Gunsight Trcking	0	5*1=5	6*4=24	0	0	0	9*9=81	2*5=10	9*7=63	0	6*4=24
Situation Awareness	9*6=54	5*1=5	6*5=30	7*5=35	8*2=16	7*2=14	9*3=27	2*2=4	9*2=18	9*8=72	0
Unusual Attiude Recovery	9*9=81	5*3=15	0	7*6=42	8*3=24	7*8=56	0	0	0	9*9=81	6*2=12
Short Term Memory w/ Distraction	0	5*4=20	0	7*3=21	8*1=8	7*3=21	0	0	0	9*3=27	0
Visual Monibring	9*4=36	5*1=5	6*6=36	0	0	0	9*6=54	0	0	0	6*3=18

TABLE 6

COMPOSITE T-MATRIX VALUES FOR EACH TEST (POP-UP BOMB MANEUVER)

G-PASS TEST	T-MATRIX COMPOSITE SCORE	RANK
Perception of Relative Motion	182	7
Precision Timing	**203**	**6**
Motion Inference	**207**	**5.5**
Pitch/Roll Capture	148	10
Peripheral Processing	171	8
Decision Making	**267**	**3**
Basic Flying Skills	132	11
Gunsight Tracking	**207**	**5.5**
Situation Awareness	**275**	**2**
Unusual Attitude Recovery	**311**	**1**
Short Term Memory	97	12
Visual Monitoring	149	9

SECTION THREE

THE G-TOOL TO OPTIMIZE PERFORMANCE (G-TOP)

One of the principal developments to be carried out under this effort involved conceptualizing a way to incorporate the assessment capability described above into the human performance model in such a way that it would be useful to the war fighter. Typically, performance models require considerable input by relatively expert users, and frequently require some degree of expert analysis of results. In the present case, the desire was to produce as close to a "turnkey" operation of the model as possible. This meant conceptualizing a vehicle in which the "expert data" would reside within the model software itself, so that the end user was required to input only a minimum of information.

In the case of acceleration stress, this means that performance results must be gathered and interpreted as part of the development program. The ultimate goal would be to develop a set of algorithms or models describing the performance effects of any G force on the human. This description would obviously involve either nominal or mean estimates of the effects, as well as their variability in a targeted population. This would be an incredibly ambitious goal for any single program. However, in the present effort, the purpose was to develop a framework that had the potential of ultimately achieving this goal. Such a framework requires the elements depicted in figure 4.

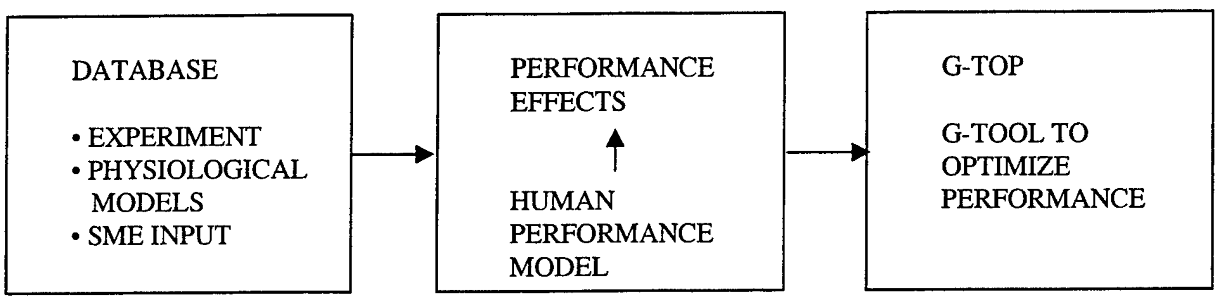


Figure 4. A framework for the development of predictions concerning the effects of G forces on performance

Database Development and Input to the Performance Model

The first requirement was to gather existing data relating G exposure to various kinds of human performance. The most desirable sources of input to the model, of course, are actual performance data collected on the centrifuge or in related situations. The literature review discussed in Section One of this report revealed that while much of the existing data appear to be quite good, there is precious little of it, and virtually no standardization. However, it became clear that a much larger body of data exists concerning the <u>physiological</u> effects of acceleration stresses. Many of these studies have been summarized (Burton and Whinnery, 1996). Further, mathematical models predicting overall G-level and duration tolerances have been developed and validated using these data (Cohen, 1983; Darrah and Klein, 1986; Harding and Bomar, 1990; Burton, 1986; Burton, 2000a; Burton, 2000b). These models essentially use calculations of the physiologic and G-related interactions that result in the final level of G tolerance (usually defined as the level of G that a seated human can attain without complete loss of vision, or loss of consciousness). It is reasonable to hypothesize that, since behavioral changes in terms of performance capability obviously accompany changes in brain perfusion, reliable inferences concerning the individual's performance capability as a function of cardiac and circulatory effects of acceleration stresses can be made. While this may be difficult and arguable in many instances, such analyses will at least provide a rational basis for estimating performance effects.

The third source of performance effects data can come from expert opinion. Subject matter experts (individuals who have experienced G profiles, as well as those who have studied them from a variety of viewpoints) can be used to supply reasonable estimates of performance effects for those conditions for which little data exist. Unfortunately, such subject matter experts are not often able to report cognitive effects reliably, precisely because the effects themselves affect cognition and affect. Thus, reports of "no effect" frequently conflict with objective data showing severe effects.

The ideal final result of these sources of performance data would be a reasonably complete set of descriptions of the effects of G forces on each of the elements or nodes in a human performance model. In an ideal world, if empirically determined data could be entered into a valid human performance model, the final effect on operational performance of all G levels, onset types, and profiles should constitute the output. However, it is clear that this goal is unattainable in any empirical way. It simply will not be possible to investigate every conceivable condition involving G forces. Therefore, the performance model itself will have to make predictions concerning those situations that cannot be directly researched. In line with this goal, three concepts were developed in this program - "G-effective" the "G-Tool to Optimize Performance", and the "Cognitive Vulnerability Map". These are discussed separately below.

The G-effective Concept

After carrying out the exhaustive literature search described earlier, it became apparent that the data, even supplemented with subject matter experts' inputs, would still leave many questions. The model that was envisioned for this program would ideally predict performance of each critical cognitive process under any acceleration level on a second-by-second basis for at least a two-minute period. In addition, it should be able to handle multiple exposures over that period of time. When the available useful data were gathered (see Table 3 in Section One above), even after normalizing, there obviously were many missing points. Due to the relative richness of physiological data under acceleration, an early conclusion therefore was that a bridge would have to be built between that data base and the performance data. Several possible approaches were investigated, including the use of transcranial Doppler data. These were found wanting for a variety of reasons, most important of which is that they were empirical techniques that offered little hope of being converted into a model of performance. Finally, a physiological model was discovered that provided the necessary (and validated) link to human performance. This was the "G-effective" model developed by Dr. Dana Rogers (Rogers, 2003).

Rogers pointed out that early mathematical models for Gz stress are generally expressed as fluid columns and are modeled in the simplest form as a ρGh pressure differential. However, this analogy is ineffective when the Gz(t) input is varying at a rate >0.2 Hz. At the higher Gz(t) rates the relationship between Gz(t) and the internal or <u>effective</u> stress Ge(t) is governed by a more complex process which must account for the effects of Gz level, rate and history. The relationship between input and output under these conditions can be expressed in a dynamic form which includes a rate dependent expression. This is accomplished by using a function of the form:

$$F(s) = \frac{1+as}{1+bs+cs^2}$$

The general dynamic stress function, F(s), has a value of 1 in the presence of a steady state input and acts as a level and time modifier when there is a dynamically changing input. This method provides a more robust means for evaluating the effective stress, "G-effective -- Ge", over time. The effective stress value, Ge(t), is calculated from the mathematical convolution of Gz(t) and F(s) which is transformed into the time domain as F(t).

$$G_z(t)* F(t) = G_e (t) \qquad \text{(*) denotes convolution}$$

Average values of the generating data were derived from the data of Stoll (1956), and are used to form F(s). This results in a Ge value which is then expressed as an average value representing a 0.5 probability of occurrence of a Gz driven event.

This method provides a continuous time assessment of the Gz stress level along any Gz input profile and represents the current tolerance along that profile. The F(s) function consolidates various G tolerance nomograms, charts, diagrams and formulas into a single expression which includes the statistical properties of G tolerance. Each G effect of interest (blood pressure, Gx,y,z, as well as head and neck stress) will exhibit different values of a, b, and c in the function.. Other modifying factors such as seat angle remain unchanged and are still valid as part of the Ge equation. The resulting processed value of Gz input is expressed as a time continuous representation of the effective stress generated in the human system Ge(t). A five term difference equation is used to compute the effective value of the Gz input. The time continuous response can be compared to the statistical steady state limit values to determine the probability of reaching a failure mode threshold at any point (blackout, unconsciousness, performance decrement, etc.)

The overall effect of this model is to predict that the hemodynamic response of the individual to an imposed G load will not parallel the actual G imposed. Instead, because of inherent lags and adaptive mechanisms in the human physiology, there will be a difference between the imposed G load and the effect on the person. For instance, the interactions in a single ramp and return test profile is shown in figure 5. The profile uses a 1G/Sec onset to a plateau level of 5.8 Gz. It demonstrates the lagging nature of the Ge value and the peak value occurring at 12 seconds into the profile. This mimics subjects' verbal commentary on concurrently observed visual effects. A subject will describe peripheral light dimming with a return to normal as the Ge value moves through the peak and returns to a steady state even though the Gz input has been at a constant plateau of 5.8Gz.

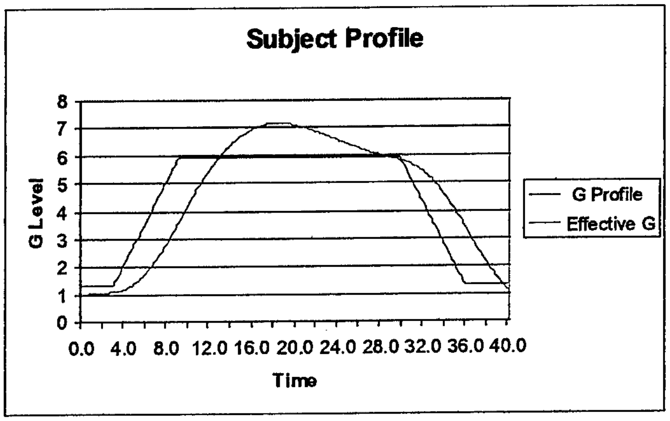


Figure 5. Simple ramp profile to steady state and return where Ge values mimic a subject's visual and verbal response.

The G-Tool to Optimize Performance (G-TOP)

As noted above, one of the major goals of this effort was to develop a user friendly tool for the researcher or operational commander to see the predicted effect of any G profile on cognitive performance. The major obstacle to achieving that goal was the scarcity of objective data. With the discovery of the G-effective model, NTI realized that <u>the literature that was available could be used as input data to the G-effective model, and that the model could then extrapolate from the existing data to provide estimates of the decrement for durations and G load where data did not exist.</u> In other words, using actual data as "tie-down" points," the G-effective model would establish what effect the person's physiological state was having on the performance of a given cognitive process. It is hoped that the combination of approximately 50 years of acceleration research in cognitive performance and the comprehensive physiological Ge model developed by Rogers will provide acceleration researchers and professionals the best prediction model available for cognitive performance under acceleration stress.

In practice, the first step in this combination was to develop a series of matrices that incorporated all of the performance data in the final data base discussed in Section One (see Table 3). Separate matrices were developed for each cognitive process and at each G level from 1 to 9 Gz (in .1 Gz increments). This provided the empirical data from which the G-effective model calculated missing data. In other words, model parameters were adjusted to fit the empirical data, and the model was then exercised to complete the matrices predicting performance decrement at that G level over time (in 1 sec. increments). This, of course, created a vast series of "look up" tables, and these form the data reservoir from which predictions can be generated for any Gz profile and rate of onset.

The next step is to generate a single table for a given profile. The operator simply inputs the desired profile on a second-by-second basis, and the G-TOP program selects the appropriate set of performance predictions at each second in the profile. This is illustrated in Table 7.

TABLE 7

SAMPLE OF THE G-EFFECTIVE DATA MATRIX DEVELOPED FOR A G PROFILE

Time (Sec.)	Gz	Eff Gz	Instrument Reading	Simple Decision Making	Visual Acuity	Complex Decision Making Accuracy	Complex Decision Making RT	Complex Decision Making Efficiency	Tracking	Slow Motion Inference	Fast Motion Inference	Spatial Orientation	Perceptual Speed
0	1.0	1.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1	1.4	1.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2	1.7	1.1	100.00	98.70	99.50	99.70	99.40	95.90	99.70	99.45	100.70	95.70	99.80
3	2.2	1.3	100.00	97.40	99.00	99.40	98.80	91.80	99.40	98.90	101.40	91.40	99.60
4	2.2	1.5	100.00	94.80	98.00	98.80	97.60	83.60	98.80	97.80	102.80	82.80	99.20
5	2.4	1.7	97.60	92.20	97.00	98.20	96.40	75.40	98.20	96.70	104.20	74.20	98.80
6	2.8	1.9	90.40	88.30	95.50	97.30	94.60	63.10	97.30	95.05	106.30	61.30	98.20
7	3.0	2.2	83.20	89.00	93.00	96.80	92.60	56.20	95.60	93.40	108.40	52.60	94.40
8	3.0	2.5	78.40	91.00	91.00	96.60	91.20	53.40	94.20	92.30	109.80	48.20	90.80
9	3.4	2.8	71.20	94.00	88.00	96.30	89.10	49.20	92.10	90.65	111.90	41.60	85.40
10	3.9	3.1	64.00	90.00	85.00	96.00	87.00	45.00	90.00	89.00	114.00	35.00	80.00
11	4.0	3.4	60.48	88.00	84.20	95.60	81.40	37.80	88.00	76.60	107.40	40.00	84.00
12	4.0	3.7	57.84	86.50	83.60	95.30	77.20	32.40	86.50	67.30	102.45	43.75	87.00
13	4.3	4.0	55.20	85.00	83.00	95.00	73.00	27.00	85.00	58.00	97.50	47.50	90.00
14	4.7	4.3	52.56	81.25	68.30	96.50	73.60	28.80	83.50	48.70	92.55	51.25	88.00
15	5.0	4.6	49.92	77.50	53.60	98.00	74.20	30.60	82.00	39.40	87.60	55.00	86.00
16	5.0	4.9	47.28	73.75	38.90	99.50	74.80	32.40	80.50	30.10	82.65	58.75	84.00
17	5.2	5.2	45.52	71.25	33.72	99.00	75.10	32.80	78.50	26.66	79.58	59.33	82.67
18	5.7	5.4	42.88	67.50	32.88	96.00	75.40	32.20	74.00	25.64	75.32	57.33	80.67
19	6.0	5.7	40.24	63.75	32.04	93.00	75.70	31.60	69.50	24.62	71.06	55.33	78.67
20	6.0	6.0	38.48	61.25	31.48	91.00	75.90	31.20	66.50	23.94	68.22	54.00	77.33

In this Table, the desired Gz level is entered into the first column by the user. For demonstration purposes, an unrealistic 20 sec. profile with a straight-line ramp up to 6 Gz is shown. In the actual program, the user can specify any realistic profile on a second-by-second basis (currently up to 60 seconds). The G-TOP program then goes into the matrix data base to select performance values (shown as a percent decrement from the 1 Gz baseline) for the designated profile at each second. This table is then available for viewing, or any of its values can be used as input to larger systems models such as CART or MANPRINT.

The Cognitive Vulnerability Map (CVM)

The G-TOP methodology described above essentially fulfills the need for a user-friendly mechanism through which the researcher or operational commander can predict the effect of any Gz profile on cognitive performance. However, if it is presented only in matrix form, it requires considerable information processing to actually visualize what is happening to the person's overall cognitive functioning. Ergonomically, such complex information is better presented graphically, so that the end user can better visualize what is actually happening. Therefore, NTI developed the concept of the Cognitive Vulnerability Map (CVM) as a method of presenting the information contained in the data matrix detailing the effects of any G profile.

The basic concept of the CVM is to show each of the nine cognitive processes as "spokes" on a wheel. Baseline 1 Gz performance is set at 100% (as shown in Table 7). For any given second of Gz exposure, the decrement (or in some cases improvement) in performance is plotted as a percent change from that baseline on each spoke of the wheel. This produces a picture of the person's cognitive status at each second of exposure for any given profile (see figure 6).

Since this series of pictures is contained in a PowerPoint presentation, the user is able to display them as a slideshow, creating a dynamic view of the predicted changes in critical cognitive processes on a second-by-second basis. In other words, the user can actually see the cognitive changes in the individual as a function of the specified G profile. This "tool" then permits the user to modify the profile, and perhaps find an alternate that will maximize cognitive performance. Further, for other purposes the user may wish to utilize these predictions to determine the cognitive effects of given scenarios. In this case, specific segments of the overall model predictions can be imported into mission models, and used to degrade the simulated pilot's performance according to those predictions.

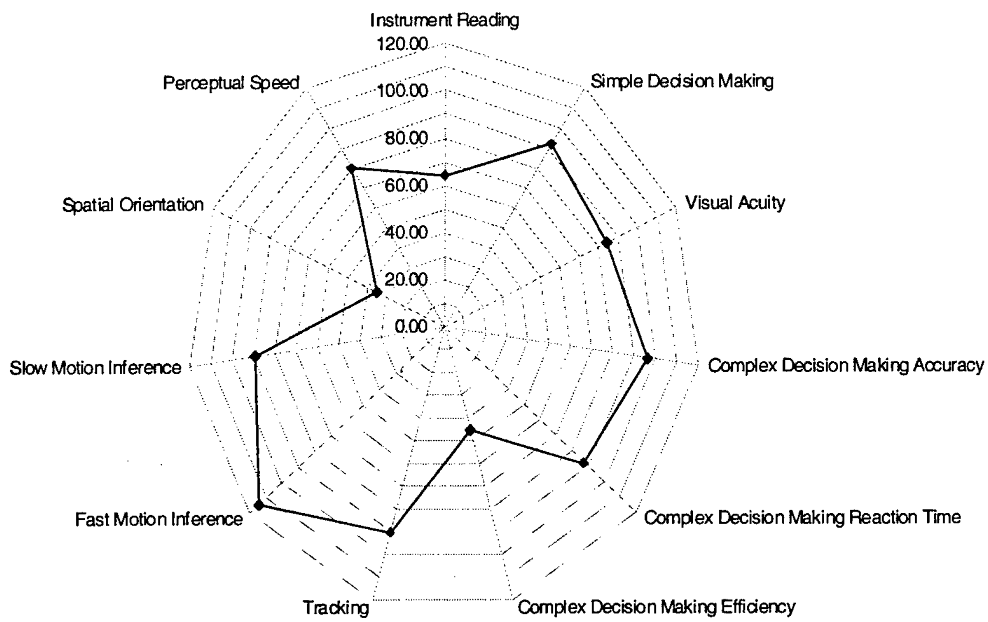


Figure 6. Example of the CVM presentation for a given Gz level.

CONCLUSIONS AND RECOMMENDATIONS

As with all innovative research efforts, it was impossible to predict the precise directions this development would take when it was first proposed. The goals, at the time, seemed difficult at best and impossible at worst. Fifty years of acceleration research had produced remarkable progress in determining and even extending physiological limits in the human. But considerably less was known about the short-term cognitive effects of increased G exposure. No coherent methodology for attacking those questions had been developed. Thus, the challenge to create such a methodology was daunting.

NTI viewed this challenge from the beginning as having two major components. One was to generate a series of performance tests specifically targeting the cognitive skills necessary for pilot performance in the high-G environment. The second was to consolidate existing data in such a way that it could contribute to a human performance model that would predict critical cognitive capabilities in any G environment. The final solutions that met these challenges differed somewhat from those originally conceptualized. However, they still were focused on the original goals, and successfully achieved them. A test battery (G-PASS) was created that hopefully will become the standard assessment tool for acceleration research, and a model of human performance was adapted from the G-effective physiological model. This was combined with a graphic presentation of the effects of any G profile on cognitive processes (the Cognitive Vulnerability Map) that moves the assessment of cognitive function in the high G environment out of the laboratory and into the operational community.

However, it would be inappropriate if some consideration was not given to the limitations of the technology developed under this program, and the need for further development. Obviously, the first limitation is that the actual data used for this effort was limited to +Gz exposures. The effects of Gx, Gy, and negative exposures is entirely absent in the present data (although data were collected for these exposures, they were even more sparse than those for +Gz, and were not sufficient for the development of the procedures). Any attempt to create a complete data base for the acceleration environment would obviously have to incorporate these additional values. Fortunately, the G-TOP methodology can easily accommodate these additional data.

A second obvious limitation of the present result is the absence of variability data. Absolute values are given for every cell in the matrices developed by the G-effective model. This enhancement to the model may be somewhat problematical, since existing data on subject variability is extremely rare. However, again, the G-TOP model can accommodate such data with some modifications, and this would provide a much richer input into larger system models. Along the same lines, the model developed here does not permit consideration of variations in performance due to other factors. For instance, extensive experience with increased G environments appears to change a person's tolerance. This is not currently reflected in the predictions. Possible gender differences are similarly not reflected. Again, while the G-TOP methodology could provide predictions about these individual differences, it is dependent on the availability of at least a minimal amount of real data, and at the present time these data are not available.

The above problem illustrates both a major benefit as well as a major limitation of the G-TOP technology. First, it is dependent on and limited by the amount and quality of objective data. The number of "tie-down points" that can be established from actual data is directly correlated with the reliability of the predictions from the G-effective model. Therefore, if there are little data available, the predictions will be more tenuous. On the other hand, the benefit of the technology is that such weaknesses will be blatantly obvious. This should be a forceful argument for the research community to recommend a program of research that would 'fill in the gaps'.

With respect to the G-PASS test battery, a similar set of questions remains to be answered. Even though the battery essentially probes skills that have been studied in great detail, the actual test procedures have been modified for the present purpose. Therefore, ideally a full set of studies should be carried out to determine the parametric characteristics of the 'new' tests. In the present context, this ideal requirement probably does not need to be realized completely, since virtually all tests used in the centrifuge in the past were "ad hoc" tests that were never subjected to the rigors of standardization. However, if the G-PASS tests are proposed as universal procedures for the centrifuge, it would be desirable to develop a plan for the gradual generation of norms for reliability and stability in the tests.

Finally, it should be noted that the predictions generated by the G-effective model are exactly that -- predictions. They are based on a selection of data from a very confusing literature. They involve a theoretical leap from hemodynamic perfusion data to cognitive performance. Although there is no doubt that they represent the best predictions available at the present time, there is also no doubt that they are wrong in many specifics. Therefore, it is incumbent on users of this technology to perform experiments that address specific predictions of this model. Hopefully, most of these predictions will be confirmed, and as converging evidence accumulates, confidence in the model will increase. Where predictions are not confirmed, the model input data should be modified, and the G-effective values should be re-calculated.

In summary, NTI hopes that what has been created in this SBIR effort is not a static product, useful to the acceleration community, but generalized methodology useful to a wide range of users dealing with the effects of stressors on cognitive performance in the human.

REFERENCES

Albery, W. B. (1990). Spatial disorientation research on the Dynamic Environmental Simulator (DES). AAMRL-SR-90-513.

Burton, R. R. (1986). A conceptual model for predicting pilot group G tolerance for tactical fighter aircraft. *Aviation, Space, and Environmental Medicine,* 57, 733-744.

Burton, R. R. (2000a). Mathematical models for predicting G-level tolerances. *Aviation, Space, and Environmental Medicine*, 71, 506-513.

Burton, R. R. (2000b). Mathematical models for predicting G-duration tolerances. *Aviation, Space, and Environmental Medicine*, 71, 981-990.

Burton, R. R., & Jaggers, J. L. (1974). Influence of ethyl alcohol ingestion on a target task during sustained +gz centrifugation. *Aerospace Medicine, 45*, 290-296.

Burton, R. R., & Whinnery, J. E. (1996). Biodynamics: Sustained acceleration. In R. L. DeHart (Ed.) *Fundamentals of aerospace medicine* (2nd Ed.), Williams and Wilkins: Baltimore.

Chambers. R. M., & Hitchcock, L. (1963). *Effects of acceleration on pilot performance*, NADC-M-6110, DTIC-AD-408686, Warminster, PA.

Chalmers, E. L., Goldstein, M., & Kappauf, W. E. (1950). The effect of illumination of dial reading (AF Technical Report 6021). Wright-Patterson AFB, OH: Air Material Command.

Cochran, L. B. (1953). Studies on the ease with which pilots can grasp and pull the ejection seat face curtain handles. *Journal of Aviation Medicine, 24*, 23-28.

Cohen, M. M. (1983). Combining techniques to enhance protection against high sustained accelerative forces. *Aviation, Space, and Environmental Medicine*, 54, 338-342.

Comery, A. L., Canfield, A. A., Wilson, R. C., & Zimmermann, W. S. (1951). The effect of increased positive radial acceleration upon perceptual speed ability. *Journal of Aviation Medicine, 22*, 60-69.

Creer, B. Y. (1962). Impedance of sustained acceleration on certain pilot performance capabilities. *Aerospace Medicine, 33*, 1086-1093.

Darrah, M. I., & Klein, E. A. (1986). Simulation of a highly dynamic G-time profile: a predictive algorithm for crewmember acceleration tolerance. In SAFE Symposium Proceedings, SAFE: Nashville.

DiBello, L., Stout, W., & Roussos, L. (1995). Unified cognitive/psychometric diagnostic assessment likelihood-based classification techniques. In P. Nichols, S. Chipman, and R. Brennen (Eds.), *Cognitively diagnostic assessment.* Hillsdale, NJ: Earlbaum. pp. 361-389.

Frankenhaeuser, M. (1959). Effects of prolonged gravitational stress on performance. *Acta Psychologica, 14,* 92-108.

Grether, W. (1971). Acceleration and human performance. *Aerospace Medicine, 42*(11), 1157-1166.

Harding, R. M., & Bomar, J. B. (1990). Positive pressure breathing for acceleration protection and its role in prevention of inflight G-induced loss of consciousness. *Aviation, Space, and Environmental Medicine*, 61, 845-849.

McCloskey, K., Albery, W. B., Zehner, G., Bolia, S. D., Hundt, T. H., Martin, E. J., & Blackwell, S. (1992). NASP re-entry profile: Effects of low-level +Gz on reaction time, keypad entry, and reach error. (DTIC-AL-TR-1992-0130). Wright-Patterson Air Force Base, OH.

Morrison, J. G., Foster, E., Hitchcock, E. M., Barba, C. A., Santarelli, T. P., & Scerbo, M. W. (1994). *Cumulative effects of +g on cognitive performance.* Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting.

Nethus, T. E., Werchan, P. M., Besch, E. L., Wiegman, J. F., & Shahed, A. R. (1993). Comparative effects of +Gz acceleration and maximal anaerobic exercise on cognitive task performance in subjects exposed to various breathing gas mixtures. Abstract, *Aviation, Space, and Environmental Medicine, 64*(5), 422.

O'Donnell, R. (2001). Comprehensive computerized cognitive assessment battery. Office of Naval Research. Tech. Report N00140-01-M-0064.

O'Donnell, R. D., Cardenas, R., Eddy, D., & Shaw, R. L. (1996). Assessing the performance impact of G-forces: Design of the Acceleration-Performance Assessment Simulation System (A-PASS). AL/CF-TR-1996-0093. AD # ADA320232.

Perez, W. A. (1986). Performance metrics for use under sustained Gz acceleration: Review and recommendations. (Biodynamic Data Bank Accession No. 45997). Wright-Patterson AFB: OH. Armstrong Aerospace Medical Research Laboratory.

Repperger, D. W., Frazier, J. W., Popper, S., & Goodyear, C. (1990). Attention anomalies as measured by time estimation under G stress. Biodynamics and Bioengineering Division, Wright-Patterson Air Force Base, OH.

Rogers, D. B. (2003). Design and safety analysis tool for amusement park rides. SAFE Symposium, Sept. 22-24. Jacksonville, FL.

Rogers, D. B., Ashare, A. B., Smiles, K. A., Frazier, J. W., Skowronski, V. D., & Holden, F. M. (1973). *Effect of modifies seat angle on air-to-air weapon system performance under high acceleration.* Memorandum-AMRL-TR-73-5. Wright-Patterson AFB, OH: AF Aerospace Medical Research Laboratory.

Sadoff, M., & Dolkas, C. B. (1967). Acceleration stress effects on pilot performance and dynamic response. *IEEE Transactions on Human Factors in Electronics.* No. 2, 103-112.

Smiles, K. A. (1973). Human performance capability in the aircraft acceleration environment of aerial combat. AD-759-174. Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, OH.

Stoll, A. M. (1956). Human tolerance to positive G as determined by the physiological end points. *Aviation Medicine*, August, p. 356.

Thorne, D. R., Genser, S. G., Sing, H. C., & Hegge, F. W. (1983). Plumbing human performance limits during 72 hours of high task load. In: *Proceedings of the 24thDRG Seminar on the Human as a Limiting Element in Military Systems*, pp. 17-40, Toronto, Defense and Civil Institute of Environmental Medicine.

Thurstone, L. L. (1943). Primary mental abilities. *Psychometric Monographs*, No. 1, Chicago: University Press.

Warrick, M. J., & Lund, D. W. (1946). *Effect of moderate positive acceleration (g) on the ability to read aircraft instrument dials.* Memorandum-TSEAA-694-10. Wright-Patterson AFB, OH.

White, W. J. (1960). Variations in absolute visual thresholds during acceleration stress. ASD-TR-60-34 (DTIC-AD-243612).

White, W. J. (1962). Quantitative instrument reading as a function of illumination and gravitational stress. *Journal of Engineering Psychology, 3*, 127-133.

Zuidema, G. D., Cohen, S. I., Silverman, A. J., & Riley, M. B. (1956). Human tolerance to prolonged acceleration. *Aerospace Medicine, 27*, 469-81.

APPENDIX A: COMPREHENSIVE LITERATURE REVIEW OF COGNITIVE PERFORMANCE ON THE CENTRIFUGE

Visual Acuity

Visual acuity is particularly critical in all of the identified tasks. Upon degradation of visual acuity, one becomes unable to monitor cockpit signals, identify friend from foe, perform formation operations, avoid missile, etc. It is clear that visual acuity is crucial in the prediction of flight performance. It has long been known that peripheral dimming occurs prior to foveal dimming under exposure to acceleration force. Because peripheral and foveal vision influence different tasks, it is important to identify decrements in both processes. For example, one is less able to detect a missile when peripheral vision is impaired. However, once a missile is detected, it is even more critical that focal vision is clear to maintain sight of the missile. White (1960) performed an experiment that measured absolute threshold of visual stimuli for both foveal and peripheral vision. Experimental runs lasted one minute, fifteen seconds and were spaced 2 minutes apart. During a run, approximately 14 alternate ascending and descending threshold determinations were made. In another study (Chambers & Hitchcock, 1963) visual brightness discrimination was studied at four levels of background luminance, at four levels of positive acceleration, and at five levels of transverse acceleration. Approximately 15 responses were made during the peak G of each run. Determinations were made at each G level with background luminance of .03, .29, 2.9, and 31.2 foot-lamberts. Visual acuity was also measured by White (1962) and Frankenhauser (1958). Results for these studies are shown in Table A1.

Table A1: Visual Acuity Data Under +Gz Acceleration.

Reference	*Dependent Measure*	*1Gz*	*2Gz*	*3Gz*	*4Gz*	*5Gz*	*6Gz*	*7Gz*	*8Gz*
Visual Acuity									
White. 1960	Absolute Threshold (Foveal)	6.66	6.76	6.92	7.19				
	Absolute Threshold (Peripheral)	3.35	3.49	3.79	3.92				
Chambers & Hitchcock, 1963	Contrast Sensitivity	9.4	10.9	11.5		15.6			
White, 1962	Contrast Sensitivity	18	18	38	44				
Frankenhauser, 1958	Percent Error of visual acuity	12.7		29.0					

Reaction Time and Decision Making

General timing ability was identified as high priority in terms of assessment due to the effect it has on several critical tasks. Timing is involved in radar lock, missile launch, seat ejection, etc. Cochran (1953) performed a study that measured accuracy and reaction times of pulling a seat ejection. On these test runs, the centrifuge accelerated to peak g with the centrifuge chamber in darkness. When the desired rate of acceleration was attained, the chamber lights were turned on, as a signal for the pilot to "bail out." The pilot then attempted to elevate his arms, grasp the face curtain handles and pull them downward, thus simulating the procedure necessary to actuate the ejection seat firing mechanism. When the face curtain was fully extended, a microswitch was triggered energizing a marker relay. A timing mechanism recorded the interval between the signal to "bail out" and "successful ejection." Though accuracy was not largely decremented, reaction times increased steadily as acceleration levels increased. A general finding exists for increased reaction time while under high gravitational force (Frankenhauser, 1958); however, circumstances during which reaction time decreases, greater error is found (McCloskey et al., 1992). Results of these studies are found in Table A2.

Table A2: Reaction Time and Decision Making Data Under +Gz Acceleration.

Reference	*Dependent Measure*	*1Gz*	*2Gz*	*3Gz*	*4Gz*	*5Gz*	*6Gz*
Reaction Time							
McCloskey et al., 1992	Reaction Time (msec)	469	449				
	Error	1.4	1.8				
	Keypad Entry RT (msec)	3514	3944				
	Keypad Entry Error	2.6	4.4				
Frankenhauser, 1958	Reaction Time (sec)	0.724	0.782				
Decision Making							
Cochran, 1953	D-Ring, % Accurarcy	100	95	93	90	100	90
	D-Ring, Reaction Time(Sec.)	1.6	1.8	2.1	3.5	3	2.8
	Face Curtain, % Accuracy	100	100	100	100	100	90
	Face Curtain, Reaction Time(Sec.)	0.5	1.5	2.5	3.9	4.1	4

Spatial Orientation

Spatial disorientation has recently been given a great deal of attention as a cause for fatality during flight. According to Albery (1990), over 70 class A mishaps involving nearly total loss of an aircraft or death of the pilot have been attributed to spatial disorientation in the U.S. Air Force alone since 1980. The ability to maintain spatial orientation directly affects one's ability to recover from an unusual attitude, monitor attitude and altitude, and to be aware of the situation around them. It also affects landing, tracking, and formation operations. Nine centrifuge panel subjects participated in a study which was accomplished in the darkened cab of the DES (Albery, 1990). In experiment 1, subjects were first trained to estimate their perception of down at 1G while the DES cab was randomly placed at several angles off of vertical (+/-120 degrees, +/-90 degrees, +/-60 degrees and +/-30 degrees). Subjects directed an arrow displayed on a TV monitor directly in front of them to their perception of down during these randomized cab positions. Subjects used a control dial to position the direction of the arrow. Five of the nine original subjects then participated in experiment 2 and 3. Their results were the most consistent at the 1Gz trials. The approach in experiment 2 was to repeat the trials previously performed at 1G in experiment 1, but with 2.0, 2.5, and 3Gz. In experiment 3, subjects repeated experiment 2, but performed the task with the CRT at an offset angle, to simulate a formation flying head/acceleration configuration. Nethus, Werchan, Besch, Wiegman, and Shahed (1993) used the Manikin to test differences in spatial orientation detection under +1Gz and +5Gz. Results for these studies are shown in Table A3.

Table A3: Spatial Orientation Data Under +Gz Acceleration.

Reference	*Dependent Measure*	*1Gz*	*2Gz*	*3Gz*	*4Gz*	*5Gz*
Spatial Orientation						
Albery, 1990	Maintenance	-3	0	0.5		
	-30 Degree manipulation	-2.5	2.5	9.5		
	-60 Degree manipulation	-2	5	6		
	+30 Degree manipulation	-1	-5.5	-7.5		
	+60 Degree manipulation	1	-3	-9		
Nethus et al., 1993	Manikin Error rate, 14 FIO2 (%)	0.125				0.175

Tracking

Several studies have investigated the influence of acceleration force on tracking performance. Tracking ability relates to every aspect of "critical task" missions. Without the ability to track, one would be unable to perform formation operations, maintain sight of a target, accurately "hit" a target, avoid collision, etc. It is and has been clear for many years that the assessment of tracking performance is crucial. Thus, this particular skill has been studied at most +Gz levels. The majority of the data located on tracking was reported as percent decrement from a 100% baseline during +1Gz. Other dependent measures of tracking are RMS error and tracking hit score. See Table A4 for data obtained from literature on tracking performance.

Table A4: Tracking Data Under +Gz Acceleration

Reference	*Dependent Measure*	*1Gz*	*2Gz*	*3Gz*	*4Gz*	*5Gz*	*6Gz*	*7Gz*	*8Gz*
Tracking									
Rogers et al., 1973	% Accuracy	100	97	90	85	80	65	50	23
Burton & Jaggars, 1972	% Accuracy	100		78		74			
Sadoff & Dolkas, 1967	% Accuracy	100					76	33	
Zuidema et al., 1956	% Accuracy	100	100		86	57			
Creer et al., 1962	RMS Error	2.9	3		3.3		4		7.5
Smiles, 1973	Tracking Hit Score	14.5	12	12.5	10	12	6	9.5	

Motion Inference

Collision avoidance was one of the nine "critical tasks" identified by the pilot consultants and government personnel. This task requires one to monitor the position of another aircraft in relation to your own to avoid collision. This task involves both the ability of precision stopping and motion inference. Precision stopping entails monitoring a stimulus, such as a moving point, while it moves toward a target. At the exact point when the stimulus reaches the target, the subject would be required to press a button. Motion inference is the same task, however, the stimulus disappears at some point and the subject is instructed to press the button when he/she thinks the stimulus would have reached the target. This tests the subject's ability to "infer" movement. This skill is necessary to test given that the pilot has to monitor more than other aircraft, thus cannot continuously maintain sight of the aircraft. Also, approaching aircraft may alternate between being in sight and out of sight. While a study that tested precision stopping under the criteria chosen for this effort was not located, a motion inference report was summarized.

Repperger, Frazier, Popper, and Goodyear (1990) performed a motion inference task that involved a noncounting procedure. In other words, they were distracted so that they did not produce a method for estimating the point of contact. This task required the subject to observe on the video display a target going from left to right across the screen for a short period of time (2Sec., 8Sec., or 16 Sec.). The target disappeared for an invisible portion of the screen and then the subject had to estimate how long a time period would be required for the target to continue moving at that velocity to reach a marker near the right edge of the CRT. See Table A5 for the data on this report.

Table A5: Motion Inference Data Under +Gz Acceleration

Reference	*Dependent Measure*	*1Gz*	*2Gz*	*3Gz*	*4Gz*	*5Gz*
Motion Inference						
Repperger et al., 1990	Time over/underestimated, 2Sec. Task	0.6		0.6		0.4
	Time over/underestimated, 8Sec. Task	0.56		0.4		0.96
	Time over/underestimated, 16Sec. Task	1.28		1.92		2.24

Dial Reading and Perceptual Speed

Warrick and Lund (1946) performed a popular study that tested one's ability to accurately read dials. Subjects were presented with 72 dials total with the numerical reading above each dial. Some numbers accurately represented the reading of the dial while some did not match the dial reading. Warrick and Lund found that significantly more error was found under +3Gz in comparison to +1Gz. Accurate dial reading simulates the ability to monitor altitude and attitude accurately. These processes are a direct test of the "critical task" of monitoring under high workload.

Frankenhaeuser (1958) modified the identical Forms Test described by Thurstone (1943) for use in the centrifuge. Each test item consists of a stimulus figure and five similar test figures (numbered 1 to 5) one of which is identical to the stimulus figure. The subject's task is to identify the test figure which is identical to the stimulus figure and report its number verbally. The test includes 60 items which were presented to the subject on cards of 10 items each. 40 of these items were presented during centrifugation. Comrey, Canfield, Wilson, and Zimmerman (1951) performed a similar study where the target picture was presented in the center of the screen and the four answer choices were presented either above, below, to the left, or to the right or the target picture. Subjects responded to the test items verbally. Recognizing an identical figure simulates recognizing a "friend" from an "enemy" aircraft. See Table A6 for the data reported in these three studies.

Table A6: Dial Reading and Perceptual Speed Under +Gz Acceleration.

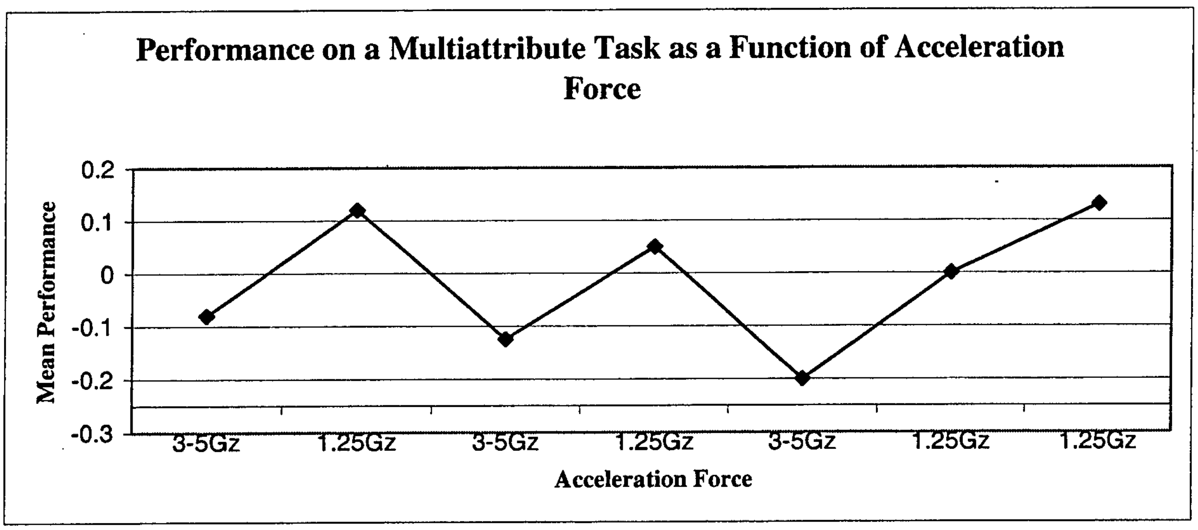
Reference	*Dependent Measure*	*1Gz*	*2Gz*	*3Gz*	*4Gz*
Dial Reading					
Warrick & Lund, 1946	Errors	3.47		4.71	
Perceptual Speed					
Comrey et al.,	T-score equiv. for raw number correct	52.59	52.32		47.62
Frankenhauser, 1958	Reaction Time (sec)	160.67		289.33	

Task Multiplexing

Morrison, Forster, Hitchcock, Barba, Santarelli, and Scerbo (1994) performed an experiment to examine the effect of cumulative exposure to acceleration force on the ability to perform more than one cognitive task at one time, multitasking. Subjects wore either a Standard Anti-G suit with Combat Edge or Eagle suit (composite data was reported because there was no significant difference). To examine multitasking, the NASA Multiattribute Task made up of three tests was administered during a SACM that varied acceleration force between 3 and 5Gz. The three tests that make up the Task are as follows.

1. Compensatory tracking task
2. System monitoring task
3. Resource management task

A composite score was adapted averaging all three scores on this task. Data was then normalized (z scores). The results of this study showed that while there was no significant difference in performance from +1Gz on the first 3-5Gz SACM, performance declined with every +3-5Gz exposure. Furthermore, performance did not return to baseline when tested post-Gz exposure. The only significant difference was from baseline to the third +3-5Gz exposure. See below for a demonstration of the results.



APPENDIX B

USERS MANUAL

THE G-PERFORMANCE ASSESSMENT SIMULATION SYSTEM

G-PASS

NTI, INC.

SEPTEMBER, 2003

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INTRODUCTION

One of the main problems in using human operator models in the high G environment is that data are usually collected under open-loop conditions. This results in performance measures that are obtained in highly artificial situations, far removed from the dynamic, interactive flight environment. Not only are critical content and predictive validity compromised by this approach, but the lack of face validity makes user acceptance very problematical. Of course, there are many valid reasons why data have been collected in this way in the past. High-fidelity aerodynamic models capable of driving a centrifuge have been limited to very expensive simulations. Even where these could be obtained, they were highly aircraft-specific, and could not easily be modified. Finally, of course, there are technical engineering problems with making any one centrifuge have both the flexibility to generate multi-axis G forces, and also have a rate of onset able to match modern aircraft.

Partly because of the above limitations, and partly because of the intrinsic nature of the forces applied to the human, performance measures typically used in such open-loop centrifuge research have been relatively simplistic. Although these studies have resulted in remarkable success in addressing the physical and physiological effects of such flight, there has been considerably less success in addressing more subtle issues of human cognitive performance limits in these environments (McCloskey, Tripp, Chelette, and Popper, 1992: Perez, 1986; Von Gierke, McCloskey, and Albery, 1991).

G-PASS (G-Performance Assessment Simulation System) was designed in response to the need for an assessment tool to be used in the centrifuge environment that measures a multitude of skills required for the performance of "critical tasks" in flight performance.

The concept of "critical tasks" was adopted in this manual for the purposes of studying only those tasks that refer to piloting missions, mission segments, or other behaviors that are critical to survival and mission accomplishment. In 1996, the AL/CFBS Branch of the Armstrong Research Laboratory invited a group of pilot consultants to address the concept of "critical tasks" that must be performed by a pilot during or after acceleration stress (O'Donnell, Cardenas, Eddy, and Shaw (1996). Together with government personnel, the pilot consultants developed a list of nine critical tasks:

- MONITORING TASKS UNDER HIGH WORKLOAD
- COLLISION AVOIDANCE
- MISSILE AVOIDANCE
- GENERAL TIMING ABILITY
- ILS LANDING
- UNUSUAL ATTITUDE RECOVERY
- MULTI-TASK CONDITIONS
- TARGET RECOGNITION
- FORMATION FLIGHT

Of course, this list is primarily phrased in terms of the fighter pilot's operational objectives. However, it does provide a form of task analysis of "critical skills" of interest. These could then be analyzed by cognitive psychologists, and translated into more basic skill or process terms that could correspond to those used in traditional centrifuge experiments. This exercise resulted in identifying the following cognitive skills of processes:

SPATIAL ORIENTATION
MOTION INFERENCE (SLOW AND FAST)
TRACKING
SIMPLE DECISION MAKING
COMPLEX DECISION MAKING (REACTION TIME, ACCURACY, AND EFFICIENCY)
VISUAL ACUITY
INSTRUMENT READING
PERCEPTUAL SPEED

During the course of the Phase I and Phase II efforts, a total of 12 tasks were developed which attempt to probe these skills to varying degrees. This "G-Performance Assessment Simulation System -- G- PASS" is described briefly in this introduction. The remainder of this manual provides detailed information directed to the user of the test battery, including recommendations about when and how each test should be used, and technical descriptions of the tests.

G-PASS TESTS

It should be noted that all G-PASS tests are designed to be operated using the Thrustmaster HOTAS Joystick and Throttle. In addition, with proper parameter settings, all tests may be run in the DES using the Elumens Dome projection system or on appropriately configured desktop PCs with standard monitors. Since the tests are primarily designed to be run in the DES with the projection dome, some (Peripheral Information Processing in particular) will not be as effective when run on a desktop. The following is a brief overview of the 12 tests in the G-PASS Test Battery. Detail Test specifications are found in subsequent sections.

STAND-ALONE TESTS

These are tests that are independent of each other.

Test 1: Perception of Relative Motion. One of the more important skills required of the pilot is to be generally aware of the relative position of one or more other aircraft with respect to his or her "own ship." This test particularly targets the critical tasks of *collision avoidance* and *formation operation.*

The task chosen to probe the perception of relative motion is a "formation join-up task" where the goal is clearly defined and the maneuvering options can be mathematically described. This is essentially a two dimensional tracking task, although it differs from traditional tracking tasks in several ways. The subject's sole task is to regulate the apparent speed of closure of two objects. The objects will consist of the image of a tanker aircraft ("target ship") and the image of a fighter aircraft ("own ship"). The fighter represents the subject and remains stationary and consistent in size. The tanker represents an aircraft outside the subject's "own ship" and will appear to move around the visual field as the subjects maneuver their "own" ship.

In the initial condition, the tanker will appear very small and some distance above the fighter. The subject will be instructed that the fighter represents his or her aircraft ("own ship"). The smaller object represents a second aircraft (tanker or "target ship") that is some distance away. The subject's goal will be to "fly" their own ship until it is "docked" with the target ship. The subjects will be practiced to the point of understanding that control actions are causing the distance between the two objects to change. As they accelerate their own ship, the second object will appear to change in size in accordance with the reduction in distance between the two objects. In other words, increasing the simulated speed of the "own ship" will close the distance between the two objects, indicated by the second object becoming larger. The goal will be to achieve a pre-defined "link-up" between the two objects in the minimum amount of time. While closing on the target aircraft, the subject will also be required to make lateral changes in position in order to make the join up from the rear of the target. The initial target position may be to the right or left of the screen, whereas the own ship will always be in the bottom center of the screen. Movement of the target aircraft will always be as if it was flying at a fixed altitude in a fixed direction with no turns, thus simplifying the task considerably.

Test 2: Precision Timing Task. The basic skill demand in this category is that the pilot visually monitor a changing situation and decide at some critically identified point to initiate a motor action. The piloting demands that require this skill involve precision timing, especially visually directed precision timing. The critical skill probed by this test is *general timing ability*, which influences decision making actions in such tasks as air-to-air and air-to-ground situations, flare decisions, formation flight, and decisions to abort landing and other activities.

In this task, the individual must monitor what appears to be a rapidly moving target for a brief period of time. An indicator (vertical line) will be randomly located at some point in the path of the target's motion. The subject's task is to press a button on the stick in order to get the target to stop on the indicator. The distance and/or time error of the subject in stopping the target at the indicator will constitute the basic measurement parameter of this task.

Test 3: Motion Inference (Time/Velocity Estimation). In the combat situation, there are instances where the individual must perceive and register the motion of an enemy or another object, then turn away from direct visual perception of the object briefly in order to carry out another task. However, the object's motion must still be processed in order to know where it should be when it is again attended to. In such cases, the individual must infer motion based on a previous perception of motion. Clearly, this places a considerable burden on working memory, especially as it interacts with short-term memory. Response selection and timing are also critical in this case. Critical tasks targeted by this test include *collision avoidance, missile avoidance, general timing ability, multitasking, and formation operations.*

This test is similar to Test 2 (Precision Timing), but utilizes a moving target that, at some designated point, disappears. The subject's task is to estimate when the object, moving at a constant rate will hit a randomly placed vertical indicator line. To stop the subject from counting or developing strategies to estimate the disappearance time, we introduced a secondary task of choosing whether a vowel was present in a string of 4 letters after the disappearance of the moving target. After responding to the secondary task, subjects are to respond when they estimate the moving target will reach the indicator line.

<u>Test 4: Pitch/Roll Capture</u>. A critical survival skill in air-to-air combat involves the ability to rapidly position the aircraft in order to move a bandit into a specific location relative to your aircraft's aiming devices. Essentially, the pilot must recognize the bandit's relative position, and then must make a rapid correction in his or her own position and attitude in order to gain the proper aiming advantage. This rapid maneuver might be in the vertical relative to the aircraft ("pitch capture"), or laterally ("roll capture"). These terms refer to the required control input, pitch or roll, which will bring the bandit into the desired position. Delays or errors in doing so will obviously have an impact o the outcome of the air engagement. Other critical tasks targeted by this test include *unusual attitude recovery* and *formation operation.*

A static simulation of the actual pitch and/or capture as it would be carried out in a fighter aircraft is used for this task. The subject sees an elementary cockpit view, with an out-the-window blue sky. At a random time into the trial, a target appears in a randomly selected position around the cockpit field of view.

The first critical element of this task is that the subject must detect the presence of an "enemy" aircraft. The subject's task is to bring the enemy aircraft into the gunsight as rapidly as possible, using a standard sequence of control behaviors. This sequence consists, first of a "roll" maneuver (tracking either to the right or the left of the screen). The goal of this roll maneuver is to bring the enemy aircraft in between two vertical lines representing the center of the cockpit. The time taken to bring the enemy aircraft within the vertical lines is a major dependent measure for this aspect of the test.

The second performance requirement in this test is that the subject must "pitch" the display forward a precise amount in order to bring the enemy aircraft finally within the gunsight. Again, the amount of time taken to complete this separate maneuver constitutes a major dependent measure of this task. As soon as the subject achieves the desired outcome, within pre-established limits, this task ends.

An important dependent measure in this task is the subject's ability and memory for sequencing the pitch/roll maneuver. The task instructions will prescribe the order in which the task must be performed. The individual should not carry out the pitch maneuver first, and any attempt to do so will result in a failure score for memory of the sequence. Similarly, if the individual attempts to carry out the maneuver on a diagonal, rather than as two separate movements describing a 90 degree angle, the trial will also be scored as a failure for memory of the sequence. Not only must the individual carry out the maneuver rapidly and accurately, but the entire maneuver must involve a coordinated series of actions.

Test 5: Peripheral Vision. The ability to detect enemy aircraft, monitor various cockpit signals, maintain sight of a missile, and many other piloting tasks are highly dependent on one's ability to use peripheral vision. For this reason, it is crucial to be able to test for one's ability to recognize signals that are directly monitored while also testing for the ability to detect signals during other tasks such as flight simulations or monitoring other tasks. This test probes the critical tasks of *missile avoidance* and *target recognition* and possibly *monitoring under high task load* and *multitasking*.

In this procedure, the experimenter will be able to present various kinds of cockpit information at any point in the visual field. Specifically, we are interested in peripheral information processing, but focal processing may sometimes be of interest. The goal is in determining whether the subject, during or after G exposure, is able to detect and/or correctly interpret various kinds of information located at differing positions on the retina. Duration of stimulus presentation, as well as the type of peripheral stimulus will be controlled by the experimenter. The dependent variables that may be of interest in this task include whether or not the subject detects the stimulus, whether movement of various indicators was detected, and the accuracy and latency of such detection.

Test 6: Rapid Decision Making. One of the most important skills considered essential to the pilot's ability is his or her decision-making capacity. It is generally believed that the ability to rapidly attend to a stimulus input, analyze it in relation to established rules and learned relationships, and then to choose between two or more alternatives through a motor action is crucial to success in the flight environment. In some cases, this involves an ability to "compartmentalize" stimulus inputs so that only information relevant to the required decision is allowed to enter into it. While this function can be inferred from the flight simulation measures, a more focused and experimentally manipulable measure is desirable.

Pilot consultants and government personnel suggested that the radar warning receiver (RWR) could provide an appropriate stimulus element for this type of function and such a display was incorporated into this test. In a low-fidelity simulation of this display, a threat is indicated by the appearance of stimuli on the scope. The subject must rapidly assess the nature of the threat, as well as its distance, and decide on an appropriate response. The test therefore assesses several aspects of working memory, as well as decision making ability and reaction timing. The critical tasks related to flight involve *general timing ability* and *monitoring under high workload.*

F-PASS-RELATED TESTS

These are tests that rely on the Flight-Performance Simulation System (F-PASS), which is an accurate PC-based flight simulator for the F-16 and other aircraft. Each of these tests is implemented as a "scenario" within the F-PASS system and all of these tests take place within the context of the Basic Flying Skills (Test 7) described below.

Test 7: Basic Flying Skills. It has been argued that "macro-cognitive" elements – those that involve complex, higher-order cognitive processes cannot be captured by combinations of simpler skills such as those tapped by other tests in G-PASS. These involve elements such as decision making, uncertainty management, and situation awareness. Therefore we decided that the best way to approach these issues in the present context is to embed them into the complex real-world tasks of simulated flight. Our goal, therefore, was to construct flight demands that introduce a number of macro-cognitive elements.

The accomplish this, a realistic aero model of the F-16 aircraft is provided as part of the test battery (F-PASS) in order to allow the researcher to examine basic flight skills. While there are some customizable options for this test, the basic mission offers a rich environment for measuring basic flight skills. The subject will "fly" that mission, either under varying G forces, or off-line after G exposure. Scoring techniques will involve standard measures of altitude, speed, and navigation errors. The critical tasks targeted by this test are the basic flying skills.

Test 8: Gunsight Tracking. Tracking is a critical task inherent in many operations vital to flight performance. This scenario requires the pilot to track a target, which is "flying" a predetermined path. The task is to be carried out in either an open loop (DES or desktop) or closed loop (DES only) manner. The primary goal is to measure the pilot's visual-motor control ability, as represented in working memory. The various metrics to be obtained will serve as direct inputs into any simulation utilizing a cognitive model, or any systems model that might be utilized. As such, the metrics for this test constitute one of the most directly applicable inputs to various types of models (i.e., any decrement in the subjects tracking ability should, to some extent, reflect the individual's likely response in the real world, without intervening assumptions). This task probes *collision avoidance, missile avoidance, ILS landing, and formation operations.*

Test 9: The Blanking Test for Assessing Situation Awareness. It is desirable to provide some measure of the situation awareness of the subject. Among the techniques designed to probe situation awareness, the blanking technique (SAGAT) described by Dr, Mica Endsley is arguably the most widely used, although it is not without its critics. In this approach, the ongoing simulation is stopped or "blanked" unexpectedly, and the subject is asked a question concerning some aspect of the situation at the moment of blanking. If the question probes a relevant aspect of the situation at the time, the subject's answer should indicate his or her level of global situation awareness.

Several kinds of probe questions can be asked. At the simplest level, the question simply asks about an environmental condition at the time of the blanking (e.g., "What is your altitude?"). More complex questions might involve anticipating the actions of an enemy or friendly aircraft, or might require the pilot to manipulate two or more pieces of information in order to answer the question.

The experimenter is able to be generate the actual questions to match the experimental design. Critical cognitive processes targeted by this test include short-term memory, situation awareness, and spatial orientation. The critical task probed involves *monitoring under high workload.*

Test 10: Unusual Attitude Recovery. The speed and appropriateness of a pilot's ability to regain straight and level flight when, for whatever reason, the aircraft gets into an attitude that is not desirable or appropriate appears to probe the immediacy of his or her perception of the situation, integration of this situation with immediate past situations and goals, and implementation of well-learned "schemas" or "scripts" for responding to the unusual situation. This test probes *unusual attitude recovery* as well as *monitoring under high workload* in the sense that if attitude and altitude are not monitored, recovery will be affected.

The task is carried out with the F-16 HUD. In an Unusual Attitude (UA), the aircraft is positioned to an attitude which, 1) could not have been anticipated by the pilot, and 2) represents a dangerous condition of the aircraft. The required response will be to recover from the unusual attitude as quickly as possible. UAs are presented following the Situational Awareness (Test 9) "blanking" period. When used in this mode, the Situational Awareness and Unusual Attitudes are combined into a single scenario.

Test 11: Short-Term Memory With Distraction. The purpose of this test is to probe the general efficiency of "short-term" memory processes and their susceptibility to disruption by acceleration forces. The term short-term memory is used here in a fairly narrow sense in that we intend to measure the subject's ability to take information in, hold it in memory for some period of time, and then act on it. The researcher has the capability of varying the time interval in which the information must be stored, the type of information processing that will be required, and the nature of the distracter.

Test 12: Visual Monitoring. A divided attention paradigm is used to probe working memory functions in the context of the centrifuge. The subject is required to monitor systems visually while performing normal flight activities. The basic concept is that any of four selected cockpit display indicators will randomly indicate a degraded condition in some system. The subject must detect the degraded conditions and take an appropriate remedial action (button press). This is not designed to make the visual detection task a threshold detection task and deviations in the displays are relatively easy to detect if scanned properly. This test more directly probes the "automatic" functions of working memory. While this test is primarily a visual detection task, some simple decision processes may be employed. This test strongly probes *monitoring under high workload.*

TEST NUMBER 1. PERCEPTION OF RELATIVE MOTION

GENERAL TEST DESCRIPTION

This is essentially a tracking task in which the subject's sole task is to regulate the apparent speed of closure of two objects. The objects will consist of the image of a tanker aircraft ("target ship") and the image of a fighter aircraft ("own ship"). The fighter represents the subject and remains stationary and consistent in size. The tanker represents an aircraft outside the subject's "own ship" and will appear to move around the visual field as the subjects maneuver his or her "own" ship.

In the initial condition, the tanker appears very small and some distance above the fighter. The subject will be instructed that the fighter represents his or her aircraft ("own ship"). The smaller object represents a second aircraft (tanker or "target ship") that is some distance away. The subject's goal will be to "fly" their own ship until it is in formation with the target ship. The subjects will be practiced to the point of understanding that control actions are causing the distance between the two objects to change. They will be required to manipulate a stick and throttle to affect this closure. Thus, this test loads heavily on visual-motor skills. As they accelerate their own ship, the second object will appear to change in size in accordance with the reduction in distance between the two objects. In other words, increasing the simulated speed of the "own ship" will close the distance between the two objects, indicated by the second object becoming larger. The goal will be to achieve a pre-defined "link-up" between the two objects in the minimum amount of time.

While closing on the target aircraft, the subject will also be required to make lateral changes in position in order to make the join up from the rear of the target. The initial target position may be to the right or left of the screen, whereas the own ship will always be in the bottom center of the screen. Movement of the target aircraft will always be as if it was flying at a fixed altitude and direction with no turns, thus simplifying the task considerably.

TECHNICAL SPECIFICATIONS OF THE TEST

The basic initial stimulus presentation to the subject is illustrated in Figure 1-1. This consists of an image of a fighter aircraft approximately .5 inch high. This image is placed in the exact center of the bottom of the viewing area, with the bottom of the image touching the bottom edge of the screen. An image of a Tanker aircraft is located at various positions toward the top of the screen above and to the sides of the center of the screen. These positions form an arc at the top of the screen. The center position on the arc is .5 inch from the top of the screen. The other positions are located on either side of the center position and are spaced equally across the screen. They are located in such a way as to maintain the same absolute distance from the bottom image as the basic target position (i.e., the arc describes a semi-circle). This second image may not be visible at this point. The starting tanker positions are randomly generated, with the constraint that no single position will be presented more than three times in a row.

The sensitivity of the control stick is set such that half full deflection in the horizontal dimension will move the target one quarter distance of the screen in two seconds (i.e., if the target started at mid-screen and the subject made a lateral displacement of the control stick by half its full deflection, in four seconds the target would leave the screen.) All other deflections are proportional to this velocity (i.e., full deflection will cause the target to move one-half the distance of the screen in two seconds.) These relationships hold for either the left or right stick movement. The sensitivity of the throttle and lateral stick movement may be adjusted by adjusting the HOTAS Cougar Joystick parameters in the Game Controllers configuration screen of the Windows Control Panel. There is a time delay (inertia) built-in between stick movement and target motion. This delay is user adjustable (see Appendix 3).

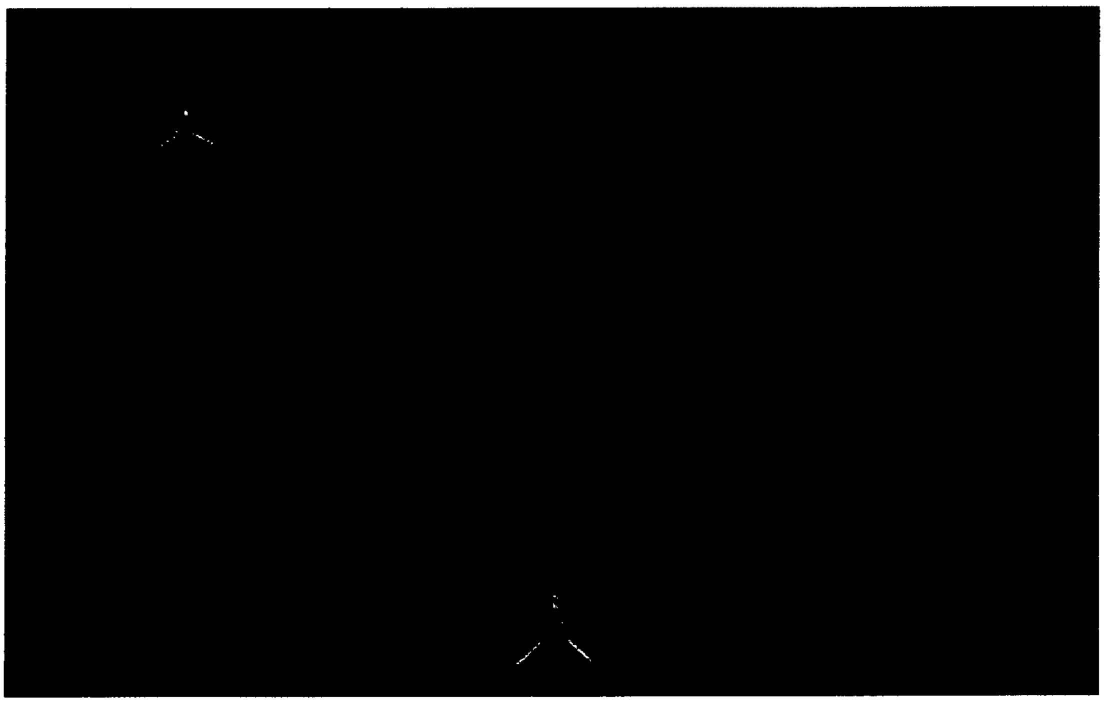

Figure 1-1: Perception of Relative Motion Interface: The subject's aircraft is represented by the Fighter image at the bottom of the screen. The Tanker aircraft image is in the upper left part of the figure. The "boom" from the Tanker has a green segment where it is safe to dock.

Movement of the throttle controls two inter-related dimensions of the target image. The first is its position on the screen. While the joystick controls lateral position, the throttle controls vertical position. In other words, as the subject increases throttle speed the target will move down the screen. If the subject decreases throttle position the target may move up the screen. Secondly, as the subject manipulates the throttle control, the target will become larger or smaller, based on the target's straight line distance to the "own" ship, not just based on the throttle. Both of these changes in the target are correlated perfectly with each other. Half forward deflection of the throttle will cause the target circle to move half the distance to own ship, and grow by half of the initial difference between it and the own ship symbol over a period of ten seconds. All other throttle changes are proportional to this.

As the subject makes control movements, the target vehicle will appear to change position and/or size. In effect, if the subject "steers" the own ship toward the target vehicle, the target vehicle will move closer to the bottom center of the screen. This would simulate the person pointing his or her own ship toward the target so that it was directly to the front. Similarly, if the subject accelerates own ship, simulating closure on the target, the target will become larger and larger.

The target (Tanker image) has a "boom", with red and green segments, trailing behind it. The boom swivels in a 90 degree arc to always point toward the own ship image. The subject's task is to have their own ship touch the boom in the green area and maintain contact for some minimum number of seconds (default is 2 seconds). If contact is broken before that time, timing is reset and a new contact period will be required to achieve the link. If contact is maintained, the trial ends, and the time that initial link-up was achieved is recorded. If the red area is touched the trial is labeled a "crash". Similarly, if the subject allows the entire target image to disappear off any edge (top, bottom, or sides) of the screen, this is considered a "miss", and the trial ends. If the subject has not achieved successful link-up within a certain amount of time (default is 12 seconds), the trial times out.

WHEN TO USE THIS TEST

This test primarily loads on visual motor control and, at its core, is a two dimensional, tracking test, although there are additional features that cause it to be somewhat different from the majority of laboratory-based tracking tasks. These include such features as having the controlled element (other ship) move in the opposite direction from controlled movements (i.e., moving the control stick to the right causes the other ship to move to the left). In addition, the use of inertia between stick movement and target motion in the system (i.e., the subject must counter previously made inputs) further limits the relationship between this test and many other forms of laboratory tracking tests. All of these characteristics have been introduced in order to more closely simulate the kinds of control actions that are essential to piloting tasks. For this reason, we believe that this task will more accurately predict pilot control behaviors.

Given the above, this task should probably be used if the experimenter is most interested in precision flying capabilities, particularly those involving perception of the relative motion of two objects in space. Situations such as aerial dogfights, formation join up, formation flying, or other multi-ship interactions would involve the skills probed by this test. As such, this test will probably be fundamental to most concerns about piloting behavior in the high-G environment. Based on previous literature, one would not expect to see large decrements in this task until the subject is exposed to approximately 4 G's and higher, but cumulative effects of multiple G exposure could be expected to show decrements in this type of performance.

TRAINING REQUIREMENTS AND PLATEAU CRITERIA

It is highly desirable that subjects reach a reasonably stable plateau prior to collecting any experimental data. Although no absolute number of training trials can be specified due to subject variability, the experimenter should at least determine that all subjects have reached a specific criterion level of performance before the experiment begins. In the present case, it would nominally be expected that a subject should reach plateau after no more than 16 series of presentations of at least 8 stimuli each. This would mean an actual nominal training time of approximately 16 to 20 minutes (not counting breaks). In order to determine plateau performance, it is recommended that the data be examined after each presentation of 8 stimuli. Running sixteen of these 8 trial sessions should produce the required training.

As performance stabilizes, we would expect to see a decrease in the mean time, and a stabilization of the variability. The experimenter is free to define any desired level of stability in these measures. However, it is recommended, that, as a minimum, the criterion be that mean performance does not improve by more than one quarter standard deviation over at least three consecutive blocks of eight presentations each. Similarly, the standard deviation should not vary by more than twenty percent over the same three blocks.

SET UP PROCEDURES FOR THIS TEST

Experimenter Options. The primary decisions the experimenter must make for this test involve the number of stimuli that must be presented (or the length of time the test is to run), and whether feedback will be given to the subject. While there are a number of additional parameters that may be set, for most experiments the default values should be adequate.

The feedback option allows the experimenter to provide the subject with feedback on each trial. This will probably be used only during training. See Appendix 3 for a description of the parameters that may be modified for this test.

Anticipated Time to Administer This Test. Nominally, it would be expected that each trial in this test would take between three and twelve seconds, depending on subject performance. Therefore, given an inter-stimulus interval of approximately two seconds, the nominal boundary conditions for administering thirty-two stimuli would be between 2 minutes 40 seconds, and 7 minutes 28 seconds. It is estimated that the average subject will complete a series of thirty-two trials in less than five minutes. It should be noted that there is no requirement that all trials be presented without breaks. In other words, four or five stimuli (or any number) could be presented at a given G level, and this could be repeated at the same G level as many times as necessary. This kind of procedure would, of course, lengthen the testing time.

SUBJECT INSTRUCTIONS

Training Instructions. The following instructions need not be given verbatim, but should cover all of the points covered in the following instructions.

THIS IS A TEST OF HOW WELL YOU CAN CONTROL A MOVING OBJECT. YOU WILL SEE TWO AIRCRAFT IMAGES APPEAR ON THE SCREEN (FIGURE 1-1). THE IMAGE AT THE BOTTOM IN THE MIDDLE OF THE SCREEN REPRESENTS YOUR FIGHTER AIRCRAFT. THE IMAGE THAT STARTS IN THE UPPER PORTION OF THE SCREEN REPRESENTS A TANKER AIRCRAFT (AT A DISTANCE) WITH WHICH YOU ARE TO "JOIN UP". THE TANKER HAS A 2-COLOR BOOM TRAILING BEHIND IT. YOUR TASK IS TO MAKE CONTROL MOVEMENTS THAT WILL BRING THE TANKER AIRCRAFT TOWARD YOU AS QUICKLY AS POSSIBLE AND TO GET YOUR AIRCRAFT TO TOUCH THE BOOM IN THE GREEN AREA AND MAINTAIN THIS "LINK-UP" FOR SEVERAL SECONDS.

YOU WILL DO THIS BY CONTROLLING BOTH THE STICK AND THE THROTTLE. THE STICK WILL CAUSE THE TANKER AIRCRAFT TO APPEAR TO MOVE TO THE RIGHT OR LEFT. THE THROTTLE WILL CAUSE THE TANKER AIRCRAFT TO APPEAR TO MOVE UP OR DOWN THE SCREEN, AS IF IT WERE MOVING AWAY FROM YOU OR TOWARD YOU. GREATER DEFLECTION OF THE STICK OR THROTTLE WILL CAUSE THE TARGET TO CHANGE POSITION FASTER OR SLOWER IN BOTH THE HORIZONTAL AND VERTICAL POSITIONS. IN OTHER WORDS, IF YOU MAKE A LARGE DEFLECTION ON THE STICK, THE TARGET WILL APPEAR TO MOVE FASTER TO THE RIGHT OR LEFT.

DURING THIS TRAINING SESSION, AT THE END OF EACH TRIAL, A SHORT MESSAGE WILL BE PRESENTED AT THE TOP OF THE SCREEN THAT DESCRIBES HOW YOU DID. "TIME" REFERS TO THE TIME IT TOOK FOR THIS TRIAL, "DIST" IS THE STARTING DISTANCE OF THE TANKER FROM YOUR AIRCRAFT, AND THE LAST INDICATOR IS WHETHER THE TRIAL ENDED WITH A "CRASH" OR "SUCCESS".

REMEMBER, YOUR GOAL IS TO BRING THE TANKER TO THE FIGHTER AIRCRAFT AT THE BOTTOM OF THE SCREEN AS QUICKLY AND EFFICIENTLY AS POSSIBLE, AND TOUCH THE GREEN PORTION WITHOUT "CRASHING" INTO IT (TOUCHING THE RED PORTION), OR MISSING IT (THE TANKER GOES OFF THE BOTTOM OR SIDES OF THE SCREEN). YOUR SCORE WILL PRIMARILY DEPEND ON WHETHER YOU MAKE THE LINK-UP SUCCESSFULLY, AND THE TIME IT TAKES YOU TO DO IT. MAKE THE LINK-UP AS QUICKLY AS POSSIBLE, BUT BE AWARE THAT CRASHING INTO THE TANKER (OR MISSING IT -- ALLOWING IT TO PASS OFF THE SCREEN) WILL BE SCORED AS A FAILURE FOR THAT TRIAL.

Test Instructions. If the subject has achieved plateau performance during the training sessions, no specific instructions need to be given concerning the test procedures. However, the experimenter must be able to explain whether the test will be given in one continuous block, or in segments, and to inform the subject how long each segment will last.

RECOMMENDED DATA ANALYSES

The subject's task is to have their own ship touch the boom in the green area and maintain contact. The scoring criterion will be that this link up lasts for several seconds. The time interval between stimulus appearance and achieving this criterion will be the basic measure for this task. In addition, we also obtain measures of "crashes" and failures to complete the link up (either because of a timeout or losing the target off the screen.)

Data storage for this test incorporates all of the individual stimulus presentations, and is coded with respect to stimulus position, time to link up, whether there was a crash (or miss), and subject identification variables. These are stored in a text file that can easily be imported into a program like Excel for further analysis. In addition, however, a number of summary statistics are calculated during the test, and are included in the data file. These include the mean and standard deviation of the link-up times, the percentage of successful link-ups, the percentages of crashes and misses, and the percentage of timeouts.

In the acceleration environment, it is assumed that the experimenter will be interested in decrement in any of these variables, either from a 1-G baseline, or as a function of the time of exposure to various G forces. Such analyses should be straightforward.

TEST NUMBER 2. PRECISION TIMING TEST

GENERAL TEST DESCRIPTION

The essential skill demand by this test is that the pilot visually monitor a changing situation, and decide at some critically identified point to initiate a motor action. The piloting demands that require this skill involve precision timing (general timing ability), especially visually directed precision timing. These include such things as decisions on weapons release in both air-to-air and air-to-ground situations, flare decisions, formation flight, and decisions to abort landings or other activities. With respect to the performance model, this task appears to require visual/motor integration at the level of working memory, but also has elements that extend over all of the nodes in the model to varying extent.

To probe this type of skill, a synthetic (not high fidelity) task was developed in which the individual must monitor what appears to be a rapidly moving target for a brief period of time. At some point in the path of the target's motion, an indicator is positioned along the target's path. The subject's task is to press a button on the stick when the target reaches that point. The distance and/or time error of the subject in precisely stopping the target at the correct time will constitute the basic measurement parameter of this task.

The screen that is seen by the subject is presented in Figure 2-1. The "target" is a moving light that traverses the curved path at different rates of speed. The subject sees the "stop point" (line perpendicular to the path) throughout the entire trial, and the goal is simply to stop the target's motion as near to the designated point as possible. As soon as the subject stops the target's motion, its location is shown on the screen, giving the subject immediate feedback on his or her performance.

TECHNICAL SPECIFICATIONS OF THE TEST

The subject will see a spot of light that will appear to move across the screen in a curved path (which will be outlined on the screen) as shown in Figure 2-1. Somewhere on the path an indicator, or "stop point" will be shown that will tell the subject where the moving target is to be stopped. Immediately after the appearance of the initial screen, the spot will begin to move along the designated path at a randomly selected speed. The subject's task will be to monitor the progress of the light toward the stop point, and to stop it precisely at the stop point by pressing a designated button on the control stick. There is an inertia associated with the dot and the subject will have to learn to anticipate when to press the response button in order to achieve successful stopping.

Once a trial has been completed, the subject will be given a brief period (default is 3 seconds) in which to inspect the results. This inspection period is user adjustable (see Appendix 2).

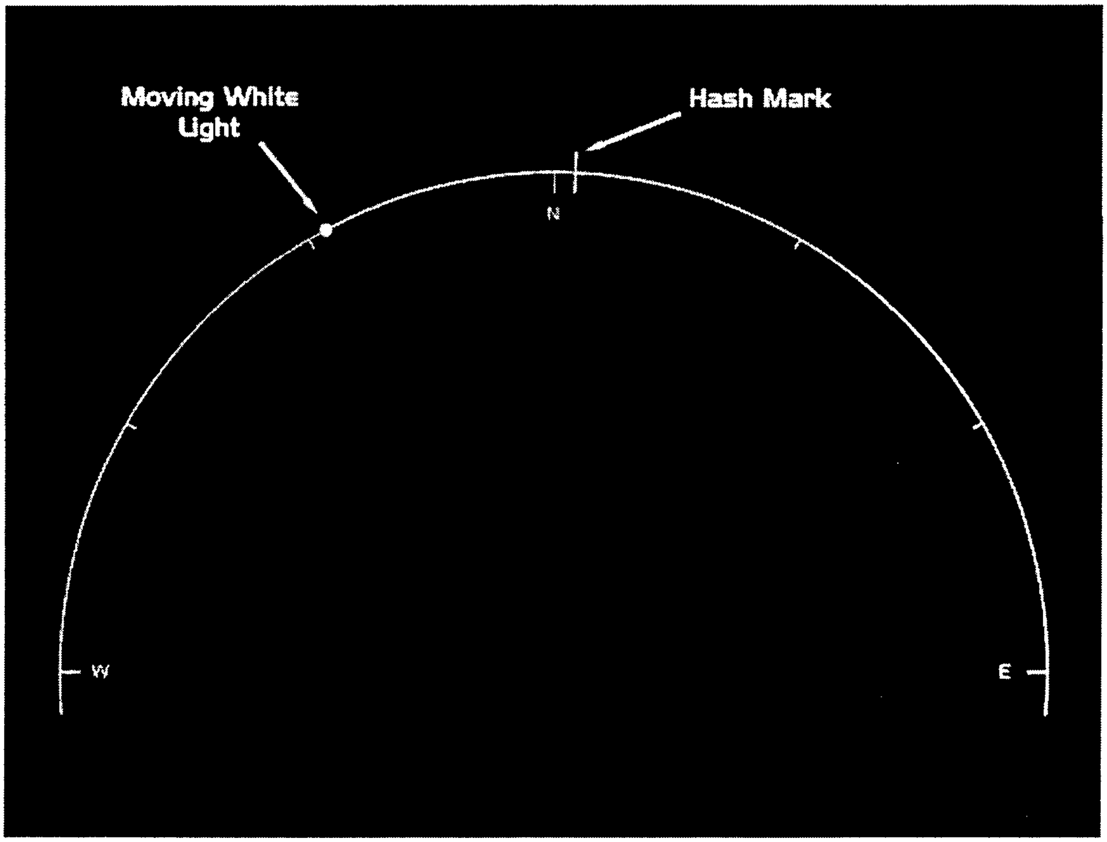

Figure 2-1: Illustration of the Precision Timing Test.

The semi-circle describing the path of the light is 60% of the screen height, with its width based on the aspect ratio of the screen. For a 19" monitor at a resolution of 1024x768, the ends of the path are approximately .75 in. from the edges of the screen and the top of the path is approximately 2.75 in. from the top of the screen. When the screen is initiated, it shows this semi-circle, along with the designated stop point (a hash mark) and a light point resting at the left end of the path. As soon as the trial starts, the moving light will go from left to right around the path described by the line.

When the screen is initiated, it shows this semi-circle, along with the designated stop point (a hash mark) and the light "dot" resting at the left end of the path. After a brief delay (user adjustable, default of 1 sec.) the moving light will go from left to right around the path described by the line. The speed at which the light moves around the semi-circle constitutes one of the major independent variables in the test. We are not attempting to achieve a "phi phenomenon" effect (apparent motion). The experimenter will be given the option to select any speed of movement within the allowable range. The default range goes from a slow movement of 4 seconds for the light to traverse the entire semi-circle to a fast movement of 1.5 seconds for the entire movement.

The point at which the subject should stop the lights is indicated by a hash mark that intersects the path. This point is randomly chosen on each trial and consists of an adjustable range of positions with the default starting 1/3 of the way around the semi-circle, and the last position 1 inch from the end of the semi-circle (see Appendix 2). The hash mark will appear simultaneously with the start of a trial and, as with the "dot", will be intense enough to be seen in any ambient lighting condition and even if the subject may be having some visual difficulties.

WHEN TO USE THIS TEST

The skills that this test are intended to measure depend heavily on visual motor coordination, but probe a much more sophisticated set of working memory processes than a simple reaction time. It is analogous to a pilot tracking a target and determining an optimum time to fire. As such, the test will be useful in assessing any change in the pilot's ability to engage successfully in either air-to-air combat or air-to-ground firing.

Based on previous literature, it is likely that this test will show decrements during low G exposures. On the other hand, one might expect fairly rapid recovery of function after such lower G exposures with significant long-term decrements occurring only after relatively prolonged High G exposures.

TRAINING REQUIREMENTS AND PLATEAU CRITERIA

Since immediate feedback is visually available to the subject after each trial (the position the dot stopped), it would be expected that learning will progress rapidly. In addition, since this is relatively simple skill, plateau should be reached fairly early. For these reasons, we do not believe that formal plateau requirements need be specified. Rather, unless, in some in very unusual situation, a subject appears to be having considerable difficulty with this task, it is recommended that each subject simply be given one 30-trial training session. The experimenter should monitor the progress of this session, being especially sensitive to extreme levels of variability from trial-to-trial. As experience with subjects grows, the experimenter should become sensitive to what appears to be an unusual variability in the subject's performance. In this case, it is probably desirable to discuss the problem with the subject and, if performance does not improve on a subsequent 30 trial training sessions, consider not using that subject for this particular test. This is expected to be an extremely rare event.

SET-UP PROCEDURES FOR THIS TEST

Experimenter Options. The experimenter has three primary options for this test. These are the number of stimuli that will be presented (or the length of time the test is to run), the speed at which the moving light progresses, and whether feedback will be given to the subject. These are each discussed below.

The experimenter can choose to have a certain number of trials run (30 is the default) or to have the test run for a certain amount of time. If time is selected, the experimenter may also set the number of trials, but the time parameter takes precedent. In this case, if the number of trials is reached before the time is reached; the program will randomly generate another set of n trials and continue until time is out. If time runs out before the number of specified trials, the test ends immediately.

The speed at which the light traverses the path will determine the relative difficulty of the task. The experimenter must decide, therefore, whether a single speed needs to be selected, or whether various speeds should be randomly produced. In most cases, the single speed of the light will be appropriate only if the experimenter has a specific question dealing with precision timing of responses at a single known condition. If one is interested in assessing the overall sensitivity of this function to a broad spectrum of movement speeds, then a random selection of speeds is appropriate.

The final option that the experimenter has is to provide feedback or not. Feedback is typically used for training. The subject receives feedback on every trial since they can observe the actual stopping point of the dot.

Anticipated Time to Administer This Test. Nominally, it would be anticipated that each trial of this test will last between 1.75 and 3.5 seconds, with a mean time of about 2 – 2 ¼ seconds. It is recommended that the minimum number of trials be 30, and that no more than 2 seconds inter-trial interval be given. This would mean that the test could take as little as (approximately) 2 minutes, or as long as 3 minutes.

SUBJECT INSTRUCTIONS

Training Instructions. The following points should be covered in the training instructions.

> In this test you will see a light appearing to move along a given pathway (Figure 2-1). At some point in the pathway, there will be a "stop point", signified by a hash mark through the pathway. Your task is to stop the light as precisely as possible at this indicator. You will do this by pressing the designated button on the joystick at the point at which you wish to stop the light. You should try not to either over shoot or under shoot the desired target. After each trial you should observe how far from the desired point you actually stopped. In some cases, the lights may move at different rates. You should take these changes in to account in making your decision to stop the light.

Test Instructions. Instructions for the actual test can be quite simple if the experimenter is convinced the subject understood all of their requirements during the training sessions.

RECOMMENDED DATA ANALYSIS

Two basic kinds of data will be produced during this test. The first will be absolute distance error from the desired stop point. The second will be a time measure in order to take the relative speed of the light into consideration. Each of these will be discussed below.

Absolute Error. The distance between the desired and actual stop points is measured as a fraction of the total path with 1.0 being a full path distance on every trial. This value can be converted to pixels if desired. In addition, all test parameters are recorded on every trial (e.g., speed, acceleration, hash position, etc.) in order to facilitate analysis. Summary statistics are produced at the end of each data file. These include the RMS error and the mean undershoot and overshoot, along with the variability of each.

Time Error. Since different speeds of the light may be used, it is desirable to calculate a measure that essentially equates the different speeds, since it will presumably be easier to be more accurate with slow speeds then with fast speeds. Therefore, the error on each trial is converted to a ratio value that considers the speed of the light on that trial.

Recalling that speed for this test is defined as the time for the target light to traverse the whole path (one semi-circle), errors may be expressed as ratios of time. Thus if the hash mark was at the 2.5 second point and the subject overshot and stopped the target at 2.7 seconds, the error ratio would be 2.7/2.5 = 1.08. These values and the summary statistics described above are output at the end of the data file.

TEST NUMBER 3. MOTION INFERENCE

GENERAL TEST DESCRIPTION

In the combat situation, there are instances where the individual must perceive and register the motion of an enemy or another object then must turn away from direct visual perception of the object briefly. However, the absent object's motion must still be processed in order to know where it should be when it is again attended to. In such cases, the individual must infer motion based on a previous perception of motion. This must frequently be done while other tasks are being performed. Clearly, this places a considerable burden on working memory, especially as it interacts with short-term memory. Response selection and timing are also critical in this case.

Although this is a situation that occurs with reasonable frequency in flight, it is not an easy one to quantify. Attempts to do so have often utilized a moving target that, at some designated point, either disappeared or was hidden from view by an obstacle. The subject had to estimate when the object, moving at a constant rate of speed, would reappear from behind the obstacle, or would "hit a target". This approach probably constitutes a good measure of the basic skill. However, it allows the subject to focus completely on this one task, and subjects sometime develop "strategies" which confound the measure (e.g., they sometimes "count beats" or sing music in time with the motion). This confounds interpretation because it is not usually the way the task has to be done in the real world. In those situations, the individual is frequently preoccupied with at least one other task while making these inferences. Therefore, it was desirable to incorporate some form of distracting task during the period of time that the subject is making inferences.

This G-PASS test is designed to address this type of performance requirement and involves having the subject view a moving light traversing a curved path. The light disappears at some point, and the subject's task is to determine when it would have reached the end of the curved path. A distracting task is introduced during the time estimation interval (recognizing vowels in a string of four letters), simulating distractions that typically occur in the real world.

This test is similar to Test No. 2 (Precision Timing) in the G-PASS battery. However, in addition to examining some of the skills probed by that test, this one adds an entirely unique skill - time/velocity estimation. Essentially, in the absence of a visual cue, the subject is required to mentally project an estimate of the time required for an object to traverse a given distance. This places considerably more demand on several aspects of working memory, as well as severely increasing the overall workload of the task.

During the task, the subject will see a moving light traversing a curved path (Figure 3-1). Approximately half way to the hash mark, the light will "go out". The subject's task is to determine when the light, continuing to move at a constant speed, would have reached a hash mark randomly placed along the curved path. The hash mark range of positions is user configurable and can be anywhere between the beginning and end of the curve, but typically located in the last third of the path. The response required is a button press when the subject believes the light would have reached the mark.

The distracting task is a simple "semantic" task. When the moving light goes out, a series of four letters of the alphabet appear on the screen (Figure 3-2). The subject must immediately decide whether any of the letters are vowels. This decision will be indicated with a response using a designated button on the stick. This interpolated task will act as a distracter to the subject in estimating the inferred motion. In this way, the subject should be precluded from using methods such as counting, tapping, or singing to infer the motion. It also simulates more closely the tasks required in the real world. Once the response to the letters is made, the subject will then estimate when the light would have reached the stop point, and will indicate this by pressing the designated button (default is the "fire" button on the joystick).

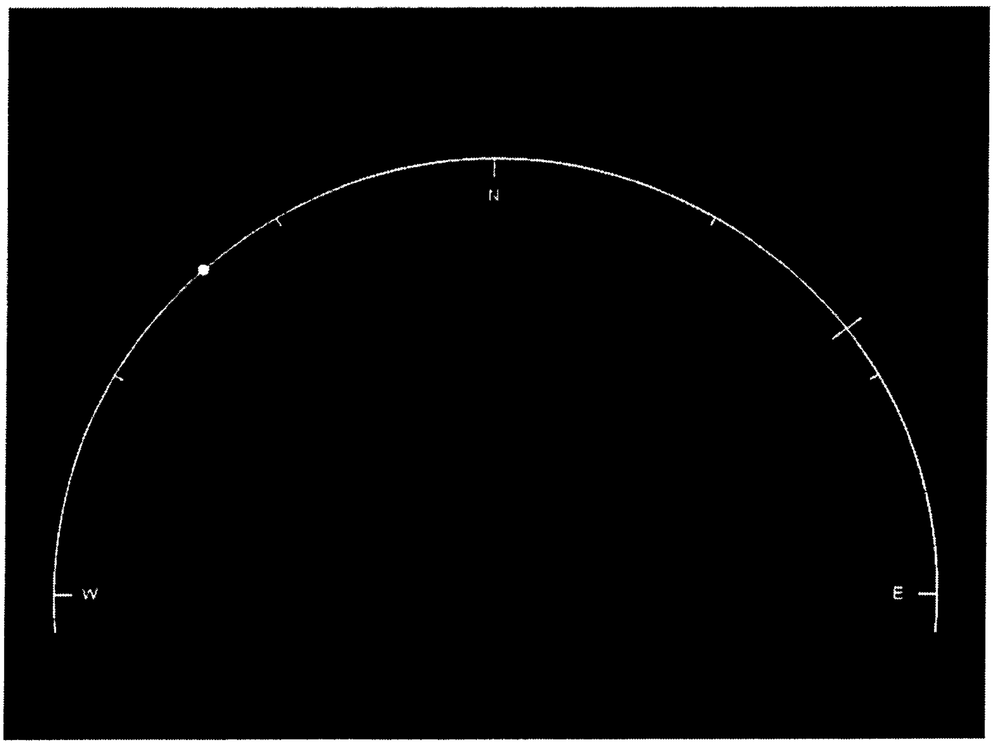

Figure 3-1: Motion Inference Test Initiation: The moving light has started around the curved path.

TECHNICAL SPECIFICATIONS OF THE TEST

The initial screen for this test is identical in most respects to that seen in Test 2, and therefore many of the technical specifications for that test are repeated here. However, there are some significant differences from that test as noted below.

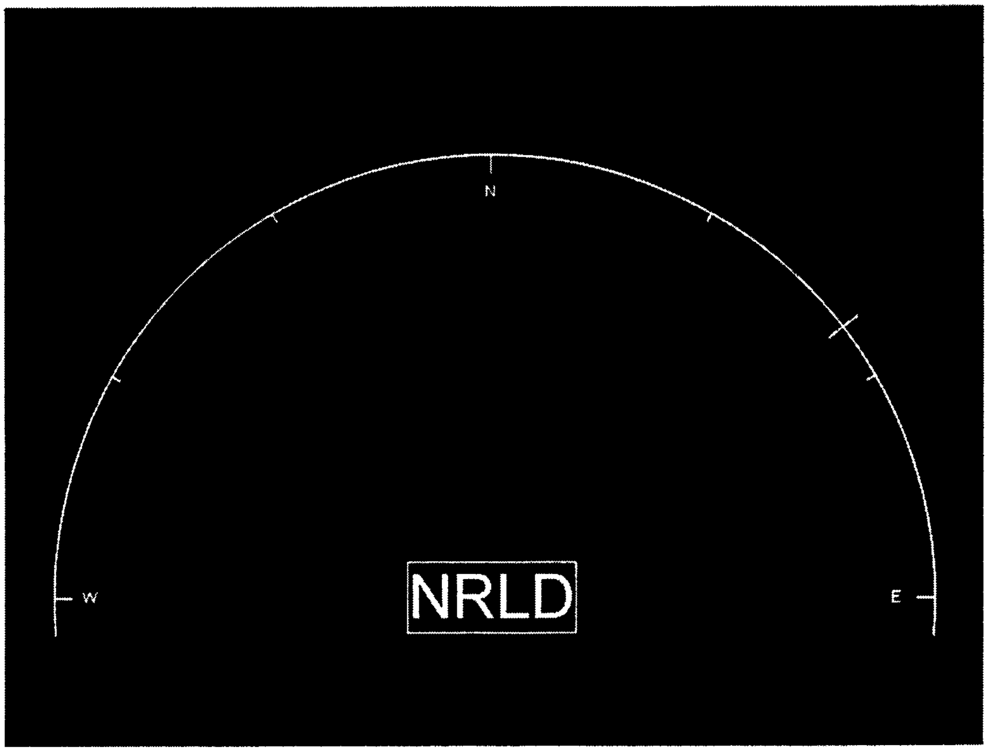

Figure 3-2: Motion Inference Distracter Task: The moving light has gone out and the 4-letter string has appeared.

The subject will see a spot of light that will appear to move across the screen in a circular path (which will be outlined on the screen) as shown in Figure 3-1. As soon as the screen appears, the spot will begin to move along the designated path at a specific speed. As in Test 2, a "stop point" (hash mark) will be designated somewhere along the pathway that the light will traverse, and the subject's task will be to stop the light precisely at this stop point. Unlike Test 2, the light will disappear some time before the stop point, and the subject will have to "infer" the motion and estimate the time it would take for the light to reach the stop point.

During the estimation interval, the subject will have to inspect four alphabet letters and determine whether any of them is a vowel. Two separate responses are therefore required: a "yes-no" response to the letters, and a "stop" response to the light. As soon as the subject makes the "stop" response, the light reappears wherever it happens to be. The subject always receives the visual feedback of where the light was stopped relative to the stop point. During training mode, the subject will receive feedback on the response to the Vowel task with the words "correct" or "incorrect" indicating the accuracy of the vowel response.

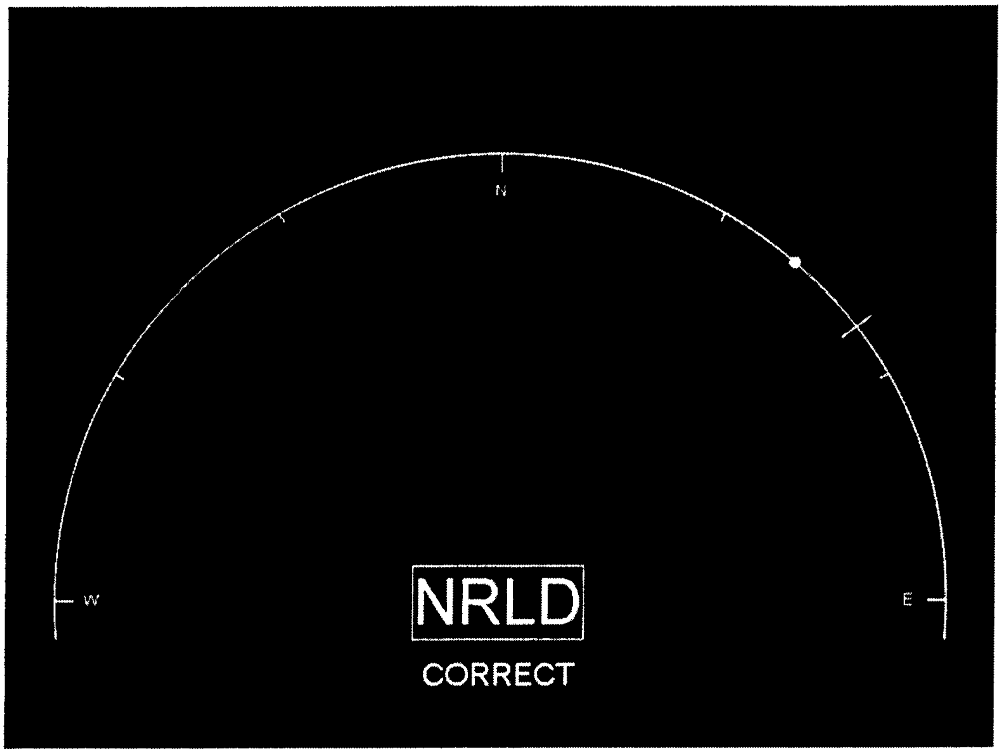

Figure 3-3: Motion Inference Feedback Screen: The correct response has been made to the string of letters (no vowel present), and the moving light has been stopped. In this case, the light was stopped too soon as it has not reached the hash mark.

The semi-circle describing the path of the light is 60% of the screen height, with its width based on the aspect ratio of the screen. For a 19" monitor at a resolution of 1024x768, the ends of the path are approximately .75 in. from the edges of the screen and the top of the path is approximately 2.75 in. from the top of the screen. When the screen is initiated, it shows this semi-circle, along with the designated stop point (a hash mark) and a light point resting at the left end of the path. As soon as the trial starts, the moving light will go from left to right around the path described by the line.

The speed at which the light moves around the semi-circle constitutes one of the major independent variables in the test. We are not attempting to achieve a "phi phenomenon" effect (apparent motion). The experimenter will be given the option to select any speed of movement within the allowable range (adjustable in the configuration program). Speeds for this test generally should be slower than for Test 2 in order to allow sufficient time for the letter response. The range for light movement can be set for any value, but typically goes from a slow movement of 10 sec for the light to traverse the entire semi-circle to a fast movement of 5 sec for the entire movement (see Appendix 2).

As in Test 2, the point at which the subject should stop the lights is indicated by a hash mark that intersects the path. This point is randomly chosen on each trial and is continuous between 0.0 (the start of the semi-circular curve) and 1.0 (the end of the curve). Typically the positions start

2/3 of the way around the semi-circle, and end with the last position approximately1 inch from the end of the semi-circle. These position limits are adjustable in the configuration program. The hash mark will appear simultaneously with the start of a trial and, as with the lights themselves, will be intense enough to be seen in any ambient lighting condition and even if the subject may be having some visual difficulties. The default position at which the light disappears from the screen is one half the way from the start of the curve to the hash mark.

As soon as the light disappears, four alphabet characters appear in the lower part of the screen at the center of the arc described by the semicircle, as shown in figure 3-2. On a 19" monitor at a resolution of 1024x768, each letter is approximately .5 in wide and .75 in high (subtending approximately .5 minutes of visual angle at a 26 inch viewing distance, in order to be large enough not to be affected by small visual acuity changes). The letters are located approximately .0625 inches from each other in a straight line.

The selection and distribution of letters for this test is critical. The random generation of letter sets conforms to the following criteria:

1) There is a 50-50 split in the probability of a vowel appearing in the sequence.
2) Only one vowel per four-letter combination is present.
3) The vowel appears in each position an equal number of times.
4) The same vowel does not appear in two contiguous trials more than twice.
5) No "run" of more than three trials is permitted for either the vowel or non-vowel conditions.

The subject's response to the vowel-no vowel task will be to press one of 2 designated buttons (on the joystick). The response to stop the light will be another designated button (default is the "fire" button on the joystick).

WHEN TO USE THIS TEST

This test is appropriate for use either off-line or on-line. There is probably no limit or requirement for a specific number of stimuli to be presented. However, because of anticipated variability in this test, a minimum of at least 16 stimuli should be given before any averaged data are considered. Ideally, 32 stimulus presentations should be used for any analyses. As noted above, this test probes multiple aspects of working memory, including task multiplexing and some semantic processing. Therefore it can be considered a fairly generic set of probes of higher cognitive functions.

This task should therefore be considered if the experimenter is interested in determining performance under high mental workload, task multiplexing, and spatial relations situations in the pilot. Because of the complexity of the task, one would expect from the existing literature that one or more aspects of performance may deteriorate at fairly low G levels, and probably would not return to baseline levels until some time after high G exposure.

TRAINING REQUIREMENTS AND PLATEAU CRITERIA

A minimum of one 32-trial set of stimuli should be used for training on this test. In most cases, this will probably not produce plateau performance. In that case, at least one additional set should be given, and this can be repeated until the experimenter is convinced that a reasonably stable plateau has been reached. In this context, a plateau must include performance on both the movement inference task and the semantic task. However, it should be remembered that instructions will be given to the subject that will indicate that the motion inference task is primary and the semantic task is secondary. Therefore, first consideration should be given to looking at the motion inference error scores to determine if they have stabilized. "Stability" in this aspect of the test means that error deviations over two eight-trial blocks are no greater than 20% of the mean deviation (although these estimates might have to be modified with continued experience in giving the test).

If such "stability" is observed, then the experimenter should inspect the data for the semantic part of the test. Any performance below 75% correct in this part should alert the experimenter that the subject is not giving enough attention to this task, and perhaps is achieving stability in the motion inference by ignoring the secondary task and even using some of the counting or other techniques that the secondary task is designed to prevent.

In that case, it should be assumed that the desired plateau has not been reached, and further training is necessary. It is recommended at that point that the experimenter re-emphasize the instructions to the subject, and give additional training sets. If a subject appears unable to handle both tasks appropriately, he/she might not be a good candidate for the test.

SET UP PROCEDURES FOR THIS TEST

Experimenter Options. The major options available to the experimenter involve selection of the speed that the light will move, setting the "stop point" range, and specifying the number of stimuli to be administered in a "set". Each of these is discussed below.

The available speeds that the light can move will typically range from 5 to 10 seconds to traverse the entire semi-circle. Normally, it would be expected that the experimenter will want a random selection within this entire range. However, in rare circumstances the experimenter may wish to specify a smaller range, or specify a constant speed.

Location of the "stop point" range defaults to a range from 2/3 of the way around to .5 inch from the end of the curve.

With respect to the number of stimuli per "set", some considerations should be noted. A full set of stimuli for this test is 32 trials. This number was chosen because it should be sufficient to approximately equalize the difficulty among different sets even with the variability that might be introduced by random selection. While fewer trials may be presented, because of subject variability, it is recommended that no conclusions be drawn from any less than a total of 32 trials.

If it is impossible to obtain a full set of 32 trials (because of environmental or subject considerations) it is recommended that the ranges of the factors discussed above be severely restricted. If it makes sense to do so for the experiment, single values for the point the light disappears, the "stop point", and/or the speed of the light should be chosen. In that case, valid conclusions might be possible with as few as eight trials.

Anticipated Time to Administer This Test. Nominally, it would be anticipated that each trial of this test will last between 6 and 10 sec, with a mean time of about 7.5 sec. As noted above, the minimum number of trials should be 32 (if all the default options are selected), and there is a 4 second inter-trial interval. This would mean that the test could take as little as just over 5 minutes, or as long just over 7 minutes. There is no need to present all 32 stimuli in one sitting, although if more than one day elapses between testing sessions, a 32 trial warm-up should be given before data are collected.

SUBJECT INSTRUCTIONS

Training Instructions. The following points should be covered in the training instructions.

In this test you will see a light appearing to move along a given pathway. At some point in the pathway, there will be a "stop point", signified by a hash mark through the pathway (Figure 3-1). Your task is to stop the light as precisely as possible at this indicator. However, at some point before this "stop point" the light will go out (Figure 3-2). You are to assume that the light is continuing along the pathway at the same speed it has been moving, even though you can not see it. When you think the light should have reached the stop point (Figure 3-3) you should press the "fire" button on the joystick. You should try to neither over shoot or under shoot the desired target. In some cases, the lights may move at different rates. You should take these changes in to account in making your decision to stop the light. This is your primary task -- to be as accurate as possible in stopping the light exactly on the stop point. As soon as you make this response, you will see where the light actually was, and in this way you can perfect your ability to make this estimation.

During the time that the light is out, you will have another task to perform. As soon as the light disappears, a series of four alphabet letters will appear at the bottom of the screen (Figure 3-2). Your task is simply to decide whether any of these letters is a vowel- A,E,I,O, or U, and to answer by pressing button 1 on the Joystick in the up direction if a vowel is present, or in the down direction if no vowel is present. Remember that you are going to be making this decision while you are trying to keep track of when the light will have reached the stop point. This letter task is your secondary task. If you find that you can not make the decision on a particular trial before you have to make a response to the light, skip this task on that trial. HOWEVER, any wrong or skipped response on the letter task will degrade your overall score. Therefore, during the training trials, you should attempt to become as proficient as possible on BOTH tasks.

After each trial you will see the absolute distance from the desired point that you actually stopped, as well as whether you were correct or incorrect on the letter task.

Test Instructions. Instructions for the actual test can be quite simple if the experimenter is convinced the subject understood all of their requirements during the training sessions.

RECOMMENDED DATA ANALYSIS

Scoring of the light portion of this test will be identical to that described under Test 2, including calculation of the 'time error' conversion described there. Interest in over or under estimation is particularly important for this test, since it probes the integrity of an internal clock which may easily disrupted by G Forces.

The semantic vowel portion of the test has been included primarily for the purpose of introducing a distracting task during the period where the subject is attempting to estimate time/velocity relationships. It was designed to be a reasonably simple task requiring some degree of attention and some degree of working memory. However, if the subject is following instructions, it is not expected that this part of the test will yield extremely sensitive data. The statistics that will be provided for this portion of the test will include the total number of correct and incorrect responses and the response time of those responses.

In addition to these simple statistics, there is considerable interest in the trade-offs subjects make between the primary and secondary tasks. It has already been stated that if the subject does not achieve at least 75% accuracy in the secondary task after stability in the primary task has been demonstrated during training, further training should be given or the subject should not be used for this test. If the subject does achieve this level of performance on both tasks, then it is possible to calculate a variation of the "throughput" metric that is frequently used with reaction time data.

This calculation involves dividing the percentage of correct responses on the secondary task by the absolute converted "time" error on the primary task. For instance, if the subject (either in training or during the 'baseline' measure for the experiment) achieves an average error of 6 sec on the light task, and has 90% accuracy, the throughput would be 90/6, or a value of 15. If the same subject, under G, maintained a 6 second error, but dropped his or her percentage correct to 60%, the throughput would be 60/6, or 10, even though the accuracy score stayed the same. Conversely, if the subject under G 'traded off' the secondary task to 60% correct, but improved performance on the light task to 5 sec, the throughput would be 60/5, or 12. In other words, the throughput would signal that the subject really did not improve performance. This throughput measure is calculated in the present test, and is available in the data file.

TEST NUMBER 4. PITCH-ROLL CAPTURE TEST

GENERAL TEST DESCRIPTION

A critical survival skill in air-to-air combat involves the ability to position the aircraft rapidly to move a bandit into a specific location relative to your aircraft's aiming devices. Essentially, the pilot must recognize the bandit's relative position, and then must make a rapid correction in his or her own position and attitude in order to gain the proper aiming advantage. This rapid maneuver might be in the vertical relative to the aircraft ("pitch capture"), or laterally ("roll capture"). These terms refer to the required control input, pitch or roll, which will bring the bandit into the desired position. Delays or errors in doing so will obviously have an impact on the outcome of the air engagement. On the other hand, if the pilot demonstrates a normal ability to carry out this type of task, it should be possible to assume that the person will be able to carry out other, less rapid "capture" tasks (e.g., formation flight).

The G-PASS test designed to probe these skills utilizes a synthetic task that is to be used off-line or in an open-loop simulation. The subject is presented a cockpit simulation (Figure 4-1) that simulates an elementary cockpit view, with an out-the-window blue sky.

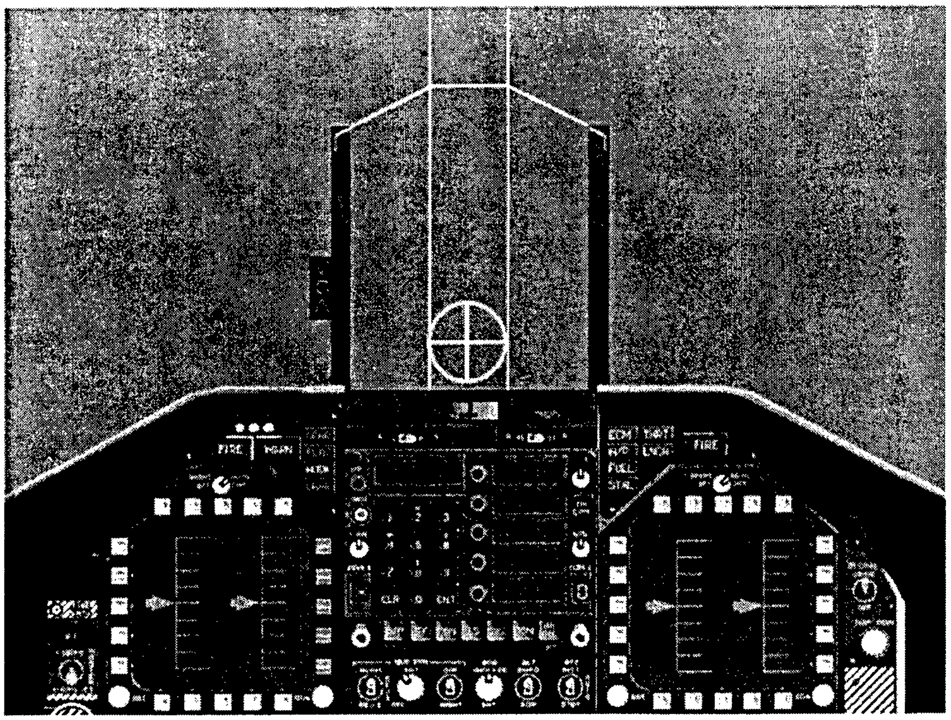

Figure 4-1: Pitch-Roll Capture Test Simulator Screen.

The essential element of this task is that the subject must detect the presence of an "enemy" aircraft, which will appear in a random positions arrayed in two rectangular regions on either side of the vertical lines going to the top of the screen. The subject must bring the enemy aircraft into the gunsight as rapidly as possible, using a standard sequence of control behaviors. This sequence consists, first of all, in a "roll" maneuver . The goal of this roll maneuver is to bring the enemy aircraft in between two vertical lines representing the center of the cockpit (Figure 4-2). The time taken to bring the enemy aircraft within the vertical lines is the major dependent measure for this aspect of the test.

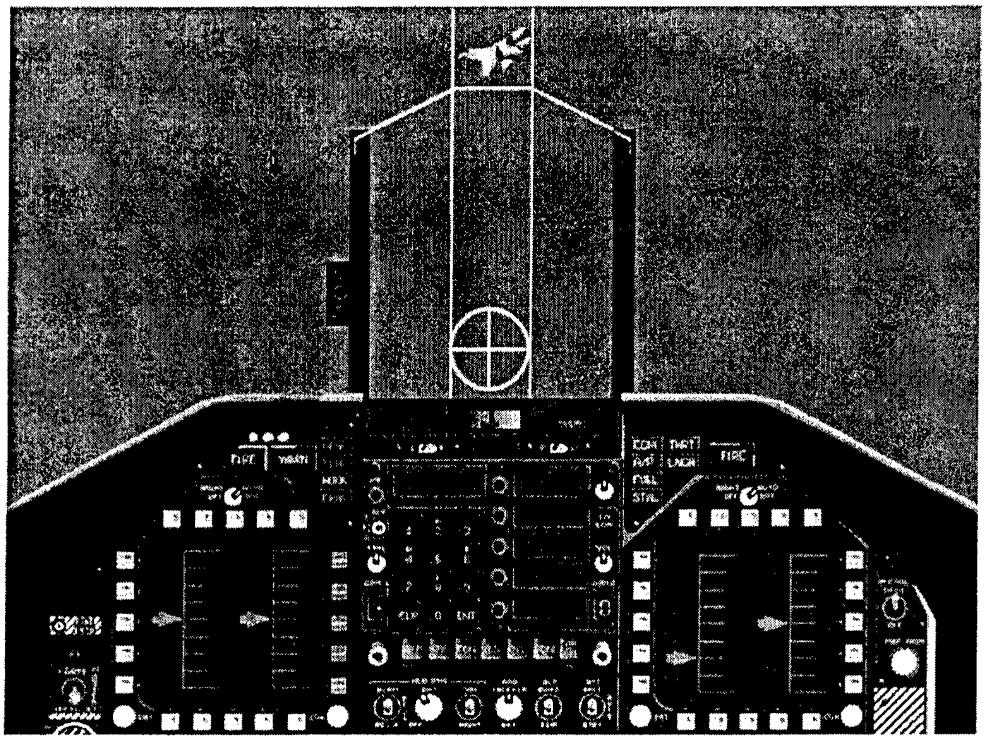

Figure 4-2: Pitch-Roll Capture End of Roll and Start of Pitch Position.

The second performance requirement in this test is that the subject must "pitch" the display forward a precise amount in order to bring the enemy aircraft finally within the gunsight. The start position for this maneuver is shown in Figure 4-2 and the end position in Figure 4-3. Again, the amount of time taken to complete this separate maneuver constitutes a major dependent measure of this task. As soon as the subject achieves the desired outcome, within pre-established limits, this task ends.

This task likely involves over-learned long-term memory functions, but also may involve spatial working memory, response selection, visual/vestibular interactions, and visual-motor control. An important dependent measure in this task is the subject's ability and memory for sequencing the roll/pitch maneuver. The task instructions will prescribe the order in which the task must be performed. Any attempt to deviate from this order will result in additional penalty as well as an error score. Similarly, if the individual attempts to carry out the maneuver on a diagonal, rather than as two separate movements describing a 90 degree angle, a failure of procedure will be recorded. Not only must the individual carry out the maneuver rapidly and accurately, but the entire maneuver must involve a coordinated series of actions.

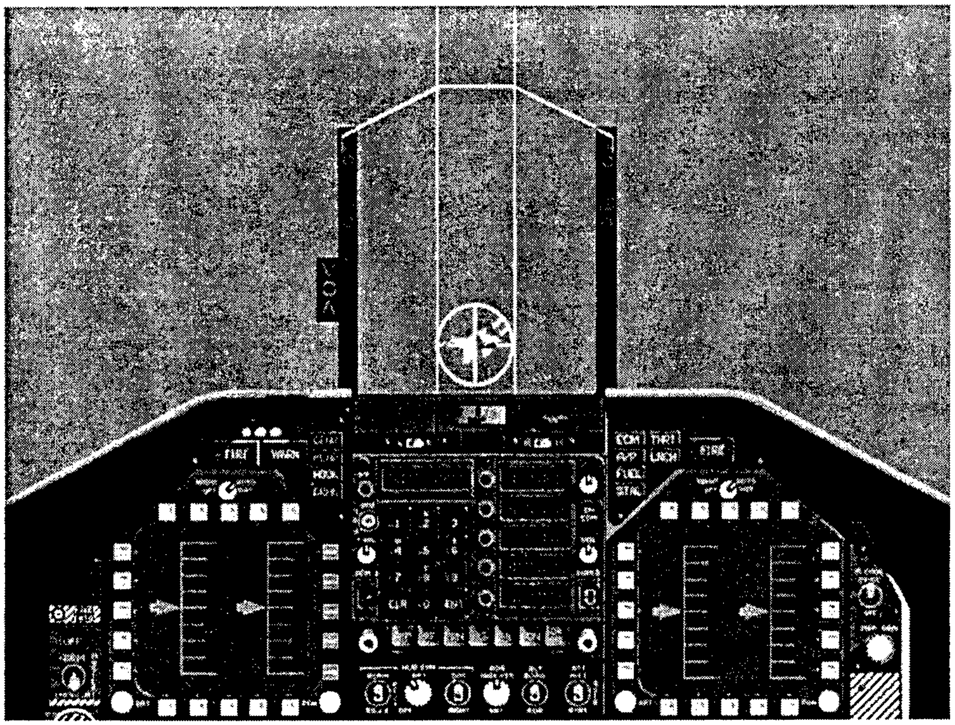

Figure 4-3: Pitch-Roll Capture Final Target Position.

TECHNICAL SPECIFICATIONS OF THE TEST

The target will appear in a randomly selected position arrayed across the screen. Target positions are contained within two rectangular blocks that lie between the edge of the screen and the edge of the HUD glass, but not touching either.

The subject will use the joystick to effect movement of the target. There is no lag between control movement and display response. Stick sensitivity is set such that full deflection, either horizontally or vertically, will cause the target to move from a center point on the screen to either side, or top or bottom, in 3 sec, in a linear fashion (no acceleration). The control dynamics are such that the target will never leave the visible out-the-window area. Once it moves to the edge of the visual area, it will remain there until control stick inputs cause it to move elsewhere.

Timing between appearances of stimuli is under control of the experimenter. The default option will cause the range to be limited to between 1 sec and 2 sec, with an average of 1.5 seconds. In addition, a time out value to end the trial without a capture is provided.

WHEN TO USE THIS TEST

This is a stand-alone test that can be used off-line or before, during, or after exposure to G. As presently configured, this test will not be used in a closed-loop mode. Since it has both procedural and visual motor aspects, it can provide evidence of the pilot's availability to utilize well-learned schemas, as well as the precision of discrete motor responses.

With respect to actual piloting skills, the test is designed to reflect the kinds of skills required when a discrete event occurs that requires a specific-well learned motor response. Such responses as correcting a critical emergency condition or initiating a maneuver to avoid a SAM require these kinds of skills. These data therefore, could be used as input to a CART model for activities such as these.

TRAINING REQUIREMENTS AND PLATEAU CRITERIA

This is a task in which it is desirable to over-train the subject. Responses during training should become relatively "automatic" to the point that the subject does not have to consciously think about the sequence of responses. Over-training in this context refers to 100 or more training trials, with feedback on every trial. Performance should be evaluated during training not only on things like reaction time (which may vary somewhat from trial to trial), but most importantly on the sequence of the responses.

At the end of training, one should never see the subject perform the pitch maneuver before the roll maneuver, nor should the subject ever attempt to effect capture by a 'combined' maneuver (i.e., flying directly to the target in one control action instead of two). If such behavior is seen at any time near the end of training, it must be corrected by additional training trials until the experimenter is satisfied that the subject has truly internalized the sequence.

With respect to accuracy measures, standard principles of stability apply. Variation in average accuracy over two consecutive eight trial blocks should not exceed 20% of the average at most, and stricter criteria may be employed by the individual experimenter if the treatment might be expected to have smaller meaningful effects.

SET UP PROCEDURES FOR THIS TEST

Experimenter Options.

The experimenter must determine the number of stimuli to be presented (or the time that stimuli are to be presented), and the timing of the appearance of the targets. Each of these options is discussed below.

Number of stimuli. Once the subject is well trained on this task, it would be expected that variability will be rather low. For this reason, it will probably be possible to utilize a fairly small number of stimulus presentations for the test (e.g. 10 to 15). Alternatively, a time can be set for running the test. In this case, if the number of trials is also set, the time variable takes precedence and the task will end only at the end of the specified time.

Stimulus Timing. The default average time between stimuli for this test will average 1.5 seconds. The default range is 1 seconds to 2 seconds.

The customizable options are described in Appendix 3.

ANTICIPATED TIME TO ADMINISTER THIS TEST.

The default average time between trials for this test is 1.5 seconds. The average default delay from the start of a trial to the appearance of the target is 2 seconds. The actual performance on each trial is expected to take 5-10 sec. with an average of 7 sec. Thus for the default condition of 15 stimuli, the test session should take less than 2.75 minutes.

SUBJECT INSTRUCTIONS

The following instructions may be given, or other terminology may be used as long as the essential points below are covered.

Training Instructions.

IN THIS TEST, YOU WILL SEE A SIMULATED COCKPIT OUT-THE WINDOW VIEW. AT VARIOUS TIMES, A "BOGEY AIRCRAFT" WILL APPEAR SOMEWHERE IN YOUR FIELD OF VIEW. THE BOGEY WILL NOT BE 'FLYING' OR TRYING TO EVADE. IT WILL STAY STATIONARY UNTIL YOU CHANGE THE ORIENTATION OF YOUR AIRCRAFT BY MAKING A CONTROL MOVEMENT. YOUR TASK IS TO "MANEUVER" YOUR AIRCRAFT IN ORDER TO PUT THE BOGEY IN YOUR CROSSHAIRS AS QUICKLY AS POSSIBLE. HOWEVER, THE WAY YOU ARE TO MANEUVER TO ACHIEVE THIS IS VERY IMPORTANT. YOU MAY **NOT** BRING THE BOGEY INTO THE CROSSHAIRS BY MOVING IT DIAGONALLY, OR DIRECTLY FROM ITS POSITION TO THE CROSSHAIRS. INSTEAD, YOU **MUST** FOLLOW THE PROCEDURES LISTED BELOW EVERY TIME.

FIRST, PERFORM A "ROLL" MANEUVER TO BRING THE BOGEY BETWEEN THE VERTICAL LINES ON THE WINDSCREEN. (Note: all of these instructions may be illustrated using the figures from this manual). YOU MUST HAVE THE BOGEY SUBSTANTIALLY BETWEEN THESE LINES FOR A SHORT TIME BEFORE MAKING THE NEXT MANEUVER.

SECOND, PERFORM A "PITCH" MANEUVER TO BRING THE BOGEY DOWN INTO THE CROSSHAIR CIRCLE. THIS TIME, HOWEVER, YOU ARE TO PERFORM THE NEXT ACTION AS SOON AS ANY PORTION OF THE BOGEY ENTERS THE CIRCLE.

THE THIRD ACTION IS TO "FIRE". AS SOON AS ANY PART OF THE BOGEY IS WITHIN THE CIRCLE SURROUNDING YOUR CROSSHAIRS, YOU ARE TO "FIRE"', USING THE FIRE BUTTON ON THE JOYSTICK. BE CAREFUL NOT TO FIRE BEFORE THE BOGEY ENTERS THE CROSSHAIRS, AS THIS WILL BE CONSIDERED AN ERROR. ONCE YOU HAVE FIRED, YOU ARE TO KEEP THE FIRE BUTTON DEPRESSED FOR AS LONG AS THE BOGEY IS WITHIN THE CROSSHAIRS. YOU ARE TO KEEP THE BOGEY WITHIN THE CIRCLE UNTIL THE TRIAL ENDS, BUT IF THE BOGEY COMES OUT OF THE CROSSHAIR

CIRCLE AFTER YOU HAVE FIRED, YOU MUST RE-ACQUIRE IT AND FIRE AGAIN.

REMEMBER -- THE ABOVE SEQUENCE IS AS IMPORTANT AS THE SPEED WITH WHICH YOU ARE ABLE TO ACQUIRE AND FIRE AT THE BOGEY.

Test Instructions.

Because training on this test is so extensive, it is unlikely that any specialized instructions will be required except those needed for the individual experiment.

RECOMMENDED DATA ANALYSIS

A variety of measures are obtained on this test. These include reaction time and procedural measures. A description of each of the measures collected is presented below.

Time to initiate first correct action. This is the time from the appearance of the target to the first lateral movement of the stick in the appropriate direction.

Roll capture time. This is the time from the appearance of the target to the time the subject "captures" the target in the vertical capture window.

Pitch capture time. This is the time between the initial roll-capture, and the final capture in the target reticule. In other words, this should be a measure of how difficult the subject found the vertical tracking movement to be.

Overall capture time. This is the time between the appearance of the target on the screen, and the final capture in the target reticule. This will probably be the most frequently used single measure for this task. The test does not record a capture unless 1) the capture window time is met (default is 2 seconds) or 2) the subject pushes the "fire" button indicating capture. This assumes in both cases that the target is within the capture area.

Procedural violations. This is a synthesized measure that is calculated as part of post-test processing. This measure is strictly meant to indicate whether or not the subject followed the specified procedure for performing this task. This procedure requires the subject to perform the roll capture and then the pitch capture. If the target enters the vertical capture window at the same (or similar) vertical position as the target started in, the Roll capture is considered correct. If the target enters the vertical capture window at any other point, lower or higher, it is assumed that the subject has not performed the Roll procedure first. This measure should be scored as either pass or fail.

Failure to achieve capture. In cases of severe performance degradation, the subject may fail to ever reach the criterion "capture" (which involves "firing" when the target is completely within the reticule or leaving the target there for 2 seconds.) This failure can occur if either the subject fires when the target is not in the reticule, or fails to position the target in the reticule for 2 seconds before the time out period.

Means and standard deviations for each of the appropriate variables above will be available in the output file immediately after the run. It is likely that the overall capture time will be the most stable of the quantitative measures. The procedural measures are likely to be less sensitive until the subject is under extreme stress, but if they do in fact change, this would be a very significant finding. Time to initial correct action may also be a sensitive measure, even at lower levels of stress. The individual times for pitch and roll probably will be useful only if the experimenter has a very specific reason for being concerned about these particular behaviors.

TEST NUMBER 5. PERIPHERAL INFORMATION PROCESSING

GENERAL TEST DESCRIPTION

(NOTE: This test, in the form described below, is applicable only to the Wright-Patterson centrifuge. The Brooks centrifuge does not have the peripheral display capability required, and only limited versions of this test may be possible.)

In this procedure, the experimenter will be able to present various kinds of cockpit information at any point in the visual field. Specifically, we are interested in peripheral information processing, but focal processing may sometimes be of interest. Interest is in determining whether the subject, during or after G exposure, is able to detect and or correctly interpret various kinds of information located at differing positions on the retina. Location, intensity, and in some cases, speed of movement can be controlled by the experimenter. The dependent variables that may be of interest in this task include whether or not the subject detected the stimulus, whether movement of various types was detected, and the accuracy and latency of such detection.

As described below, the experimenter may choose to use any of four types of stimuli (small spot of light that is stationary or moving, a round pointer display, and a vertical pointer display). This choice is dependent on what question the experimenter is interested in answering (see "When to use this test" below).

In the case of simply determining whether the subject sees the point of light, the procedure is relatively straightforward. A central fixation point is provided, and the subject reports when the light appears by pressing the appropriate response button. If the experimenter is interested in determining whether the subject can detect simple motion of a point of light, the light will be on and the user will make an appropriate response when the movement of the light is detected. However, in this case, the experimenter has the option of having the subject detect the direction of movement as well (which will depend upon the type of stimulus selected).

If either pointer stimuli are used, the same basic procedure is employed. However, in this case, the stimuli should be present in the periphery at all times. The subject must be looking at the fixation point in the central field, and must detect when the pointer moves and, if the experimenter wishes, must also indicate the zone the pointer is in (without looking directly at it).

If the experimenter wishes to make the discrimination task more difficult, and ensure that the subject can not look directly at the dial, the "Parallel presentation" mode permits identical pointer displays to be placed in the same peripheral locations on the right and left sides (this is the default mode). In this case the subject is to look straight ahead at a fixation point, and to detect whenever any of the pointer displays move.

TECHNICAL SPECIFICATIONS OF THE TEST

All stimuli can be presented anywhere within the projection area of the centrifuge dome, except where the central instrument panel is located. In all cases, a high-contrast, "X" that subtends a visual angle of about 20 min. of arc at a viewing distance of 26 inches is presented in the middle of the dome as a fixation point. Four types of stimuli are selectable by the experimenter.

The first two stimulus types use a small spot of light designed to subtend a visual angle of about 20 min. of arc at a viewing distance of 26 inches. This spot of light can be presented either in a stationary mode, or as a moving spot. In the case of movement, the spot moves at a user selectable speed. Typically these speeds will be between 1 degree per second and 20 degrees per second, in increments of 1 degree per second (default option is 2 degrees per second). The light can move either vertically or horizontally. Intensity of the moving light is the same as described above for the stationary light. The interstimulus interval for the spot of light is user selectable and typically ranges from 2 to 20 seconds.

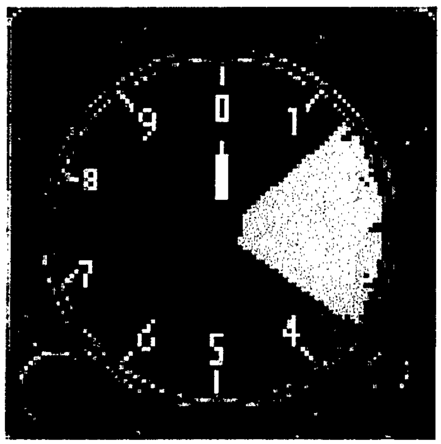

Figure 5-1: Peripheral Processing Round Pointer Dial.

The third type of stimulus is a round pointer dial (shown in Figure 5-1). The size of the dial is typical for an aircraft instrument. It is a white on grey dial, in which the background is grey, and the pointer-needle white. Around the periphery of the dial, the right 180 degrees of the circle is divided into three "zones". The top 60 degrees of the zone are green, the middle 60 degrees are yellow, and the bottom 60 degrees are red. Of course, it is recognized that color will not contribute to any discrimination by the subject in the periphery, since there are few or no cones out beyond a certain point in the retina. However, color is added for those cases where the experimenter might want to present the stimuli closer in to the fovea. In addition, around the dial itself, ten numbers are presented, separated equally, starting with 0 at the top.

The pointer of the dial itself extends from the center of the circle to an area halfway into the colored portion of the dial. It subtends approximately 30 min. of visual angle at a nominal 26 in. viewing distance. The speed of dial movement is selectable by the experimenter and is typically between 1 degree per second and 20 degrees per second, in increments of 1 degree per second (default option is 5 degrees per second). The initial position of the pointer at the start of each trial is always 0 degrees.

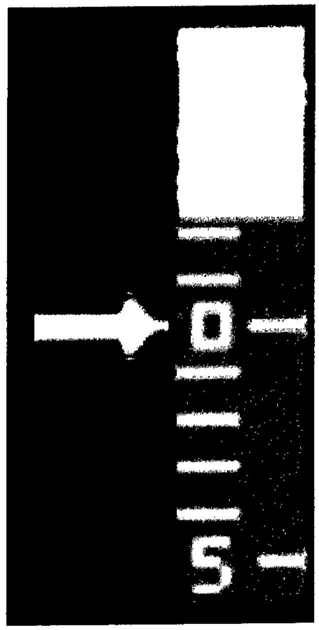

Figure 5-2: Peripheral Processing Vertical Pointer Display.

The fourth type of display is a vertical indicator with a needle dial moving up or down (Figure 5-2). The vertical visual angle of this display in the centrifuge approximates the visual angle of the VVI display in the F-16 aircraft. The characteristics of this display are similar to the round dial display described above, with the red-green-yellow areas occupying one-third of the vertical dimension each. The pointer on this display is an arrow that normally is stationary in the middle of the dial. At an experimenter-designated time, the pointer will move toward either the red or yellow zone, at a user selectable rate in degrees/second (default is 5 degrees/second). The pointer is white on a black background and extends one-half the horizontal size of the display.

WHEN TO USE THIS TEST

The experimenter options provided for this test are designed to cover several areas of potential operational interest. The decision of which options to employ should be made based on which area of operational concern is most important. The simplest question might involve whether the pilot can detect the "glint" of another aircraft, or the firing of a weapon during or after G exposures. In this case, the "point" stimuli can be used with the stimulus duration set so the light appears as a “flash” of light.

Since the periphery is sensitive to movement, a separate question might be whether the pilot can detect and perceive the direction of movement in the periphery (e.g., perceive and react to the movement of an aircraft). In this case, the "Moving point" stimulus should be used, and the experimenter has the option of requiring the subject to simply detect the movement, or to indicate its direction.

A separate and more sophisticated set of questions involves the subject's ability to process information from indicators in the periphery. Although most aircraft dials are located centrally, it must be remembered that as the pilot moves his or her head around to look outside the aircraft, the central dials suddenly become peripheral dials. Therefore, as a minimum, one might be interested in whether the pilot can detect and process changes in these dials. If this is the interest, then the dial options should be used. As noted above, this option should probably most often be used in the "parallel presentation" mode (dial stimuli on both sides of the periphery with a fixation point in the center of the display area).

Since this test is unique in the acceleration literature, all of the situations in which it might be useful probably can not be anticipated. In general terms, this test likely probes the perceptual input portion of the information processing model in ways that have not been done extensively before. As such, it opens up the possibility of systematically plotting the effects of specific G exposures on various kinds of peripheral information processing requirements. In other words, systematically determining what kinds of information can be processed at various peripheral locations during and after different G exposures. Investigations of helmet-mounted displays should also find several uses for this test. With the possibility of using wide-area surround displays on the helmet, questions of symbology, location, size, etc. become important at all points in the visual field. It is expected that this test will play an important part in defining those requirements.

A potential problem in utilizing this type of test stems from the difficulty of assuring that the subject's eyes are fixated at the point desired by the experimenter in order to locate the peripheral position of the stimulus with some degree of precision. A tempting approach is to provide a primary task that would occupy the subject's focal vision. This may be possible in some cases, especially if interest is in simple detection of the spot of light. However, it should be remembered that this introduces a dual-tasking situation, with all of the accompanying problems of determining distribution of attention. Therefore, the experimenter would have to be extremely careful, even in the simple detection paradigm, to introduce the task peripherally at a time when the subject's attention is focused on the focal event, but when the focal event is not so attention-consuming that it would be unlikely any peripheral event would be detected.

Another technique for assuring that the subject is looking at a particular point is to briefly present dials at corresponding retinal points on <u>both sides.</u> In other words, the subject is required to attend to <u>both</u> stimuli. Subjects can probably be practiced on this task to a high degree of accuracy. If the dial stimuli are used, this is probably the preferred method of utilization. It may be less desirable if one is interested in simple detection of motion. It should be remembered, however, that this focuses the subject's attention on the peripheral stimuli. While this is desirable in many cases, it does not simulate real-world conditions in which the periphery is usually relegated to a secondary focus of attention.

TRAINING REQUIREMENTS AND PLATEAU CRITERIA

Training on this test should be relatively simple. In the case of flash or simple movement detection, a few familiarization trials should be sufficient, and unless subjects show a complete lack of understanding, no formal plateau criteria should be necessary. However, during the training sessions, it is critical that the experimenter monitor the subject's behavior to determine whether he/she has a tendency to rapidly try to foveate a detected peripheral stimulus. The subject will be instructed not to move his/her eyes whenever a stimulus appears, but to look constantly at the central stimulus. If undesirable behavior is detected, additional training trials must be given until the subject has overcome this tendency. Training on the task to identify the zone that a dial is in may be somewhat more difficult. However, it should still require less than 30 training trials, and it should be obvious whether the subject has reached plateau, without any formal statistical analyses.

If the option to present the stimuli in two corresponding peripheral locations is chosen, training may be considerably more difficult. This is a fairly demanding attentional task, and some subjects might find it extremely difficult, while others find it relatively easy. A suggested criterion is that if a subject, after about 45 training trials, is still showing random success, it should be concluded that he/she is not a good candidate for this test. On the other hand, a consistent success rate at or above 75% over 15 to 20 trials is probably a good acceptance criterion.

SET UP PROCEDURES FOR THIS TEST

Experimenter Options. This test presents a variety of options and decisions that the experimenter must make in setting it up. The first of these is the type of stimulus to be employed. If interest is simply in whether the subject can detect a peripheral event, such as a glint from an aircraft, then the "point" stimulus is appropriate. If interest is in determining whether the subject can detect movement, then the "moving point" stimulus would be selected.

The first decision is which type of stimulus the experimenter wishes to have presented during this experiment. Only one type of stimulus may be selected for any given experiment. As noted above, the four possible selections consist of the following: 1) a "point", which is a dot of light, 2) a "moving point" which is a dot of light that moves in one of several selectable directions for a designated period of time, 3) a "circular dial", or 4) a vertical strip dial.

Point Stimulus. If the "point" stimulus has been selected, the designer must select the number of stimuli to be presented and the intensity level. Any number of stimuli, can be selected, and the default option will present 30 stimuli. The duration defaults to 15 seconds. The software will present the requested number of stimuli randomly within the range of interstimulus intervals specified by the designer (default is 1 – 2 seconds with an average of 1.5 seconds).

The location of the stimulus presentations must next be chosen. This is done by considering the dome as being divided into 15 horizontal and 15 vertical segments. This creates a 15 X 15 matrix (225 cells). Each of these is designated by an X-Y coordinate. The designer must specify the area (or areas) in which he/she wishes the stimuli to appear. For instance, if the experimenter wishes to present stimuli over the range of horizontal locations in the left and right visual fields, and only in the midline, he/she would enter coordinates X=1 to 4, and Y = 8 for the left field, and X=12 to 15, and Y= 8 for the right field. This is the default setting. The computer will randomly present stimuli in these regions only, with no constraints on repeats. Note that certain cells in the matrix are prohibited from selection. These are in the area that is covered by the instrument displays in the center bottom of the dome. To randomly position the stimulus over the entire dome, X=1 to 15 and Y=1 to 15.

Moving point stimulus. If the "moving point" stimulus is selected, the designer must select the same parameters as for the Point Stimulus. In addition, the designer must select apparent movement speeds in degrees/second. The default speed is 2 degrees/second. In addition, the experimenter is provided with the option of having the stimulus move.

The designer must specify the number of stimuli to be presented, as well as their location and timing. In this case, selection of the coordinates for each stimulus presentation will determine the starting point for the moving point. Within the coordinates selected, stimuli will be presented randomly, without regard to right or left (unless coordinates on only one side have been chosen).

Round or vertical dials. If either the round or vertical dial option is chosen, the same options are available to the designer as for the point stimulus. In this case, however, the dials should always be located in the midline periphery (i.e., Y coordinates of 8). The only choice that the experimenter must make is in the range of X coordinates. Selecting an X coordinate will locate the upper left corner of the vertical display, and the upper center of the dial display.

The final choice that the designer must make is whether each stimulus should be presented separately, or with a "mirror image" in a corresponding retinal location. As noted above, this is one technique to help assure that the subject does not immediately foveate a peripherally presented stimulus. If the "Parallel presentation" option is chosen for either the round or vertical dial, the computer will present an identical stimulus at the identical non-relevant ipsilateral peripheral position. However, this stimulus will not portray the relevant parameter of the other stimulus. For instance, if the interest is in detecting movement in the display, and the movement is on the right side, the left periphery will present the display without movement.

Anticipated Time to Administer This Test. To a large extent, the question of test length is up to the experimenter. Nominally, it would be expected that the average interstimulus interval will be 2 seconds or less. The default number of stimuli is 30. It is anticipated that each trial will take 10-15 seconds. Thus a nominal test will take six to eight and a half minutes. Of course, the experimenter can lengthen or shorten the test time by setting the interstimulus interval range, within the limits set by the software.

SUBJECT INSTRUCTIONS

Subject instructions for this test will vary depending on the selections the experimenter has made. Therefore, no "canned" instructions are given here. However, certain things should be emphasized no matter what the particular experiment configuration happens to be. For instance, it should be emphasized to the subject that he/she is to look directly at the central stimulus. It may be desirable to discuss with him or her the tendency to "look at" the peripheral stimulus as soon as it is detected, and that this should not be done.

Instructions when either of the dials is used, and where the subject must identify the zone that the moved dial is in, need to be explicit. The subject should be told that at some point, one of the dials will change position and that, without looking directly at it, the subject is to identify which dial has moved (right or left), and possibly the zone that it is now in (red or green).

RECOMMENDED DATA ANALYSIS

The basic data of interest in this test are the detection times, correct perception of the direction of movement, and correct or incorrect detection of the location of a dial. For the non-moving spot of light, only the detection latency is available, and this is summarized in terms of mean, variability, and missed stimuli. For all other stimuli, in addition to the above, the correct or incorrect responses indicating stimulus movement direction or location are summarized.

TEST NUMBER 6 - RAPID DECISION MAKING

GENERAL TEST DESCRIPTION

The ability to attend rapidly to a complex stimulus input, analyze it in relation to established rules and learned relationships, and then to choose between two or more alternatives through a motor action probably constitutes a "macro-cognitive" skill. In some cases, this involves an ability to "compartmentalize" stimulus inputs so that only information relevant to the required decision is allowed to enter into it. Since this ability is considered critical to so many activities, it is essential that it be measured, even though it is one of the more complex and difficult skills to probe.

In the past, NTI has used a simulation of the radar warning receiver (RWR) display as the stimulus element for probing this skill. In this display, a radar threat appears at various positions on the panel. Typically, an auditory warning accompanies the appearance of the stimulus on the scope. The pilot must rapidly assess the nature of the threat, as well as its severity, and decide on an appropriate response. The test, as previously implemented, was complex, and depended heavily on the subject's piloting skills. In the present case, it was desirable to keep the essential elements of this test, but to generalize the skills involved, as well as making the test less complex.

The basic concept of the present version of this test is to present the subject with a display containing three "areas" that will represent three levels of unspecified "danger" (see figure 6-1). These areas will be clearly identified (optionally color coded) with respect to the level of danger. At various times, symbols will pop up on the display indicating that "vehicles" have entered into the areas. The vehicles will appear as any of three types of symbol. One type will clearly indicate that the vehicle poses some threat, but the threat is low. Another will indicate that the vehicle is a clear and severe threat. A third type will indicate that it is a "medium" threat. The subject's task is to decide on the level of threat, based both on the type of vehicle and the area of the display in which it is located, and to make a differential response based on that decision. This is to be done as rapidly as possible, and the test will be paced so that only a short period of time will be available to make the decision before the next stimulus appears. In essence, this test is a complex choice reaction time test where higher level cognitive processes must be used to determine what the stimulus means.

TECHNICAL SPECIFICATIONS OF THE TEST

Stimulus Characteristics.

The simulation used in this test will consist of a round display containing two concentric rings creating three distinct areas within the display (figure 6-1). The outer area is designated as an "alert" area (green), simulating a potential threat. The middle area is designated as a "danger" area (yellow) and the third area is designated as a "critical" area, signifying that the threat is imminent (red).

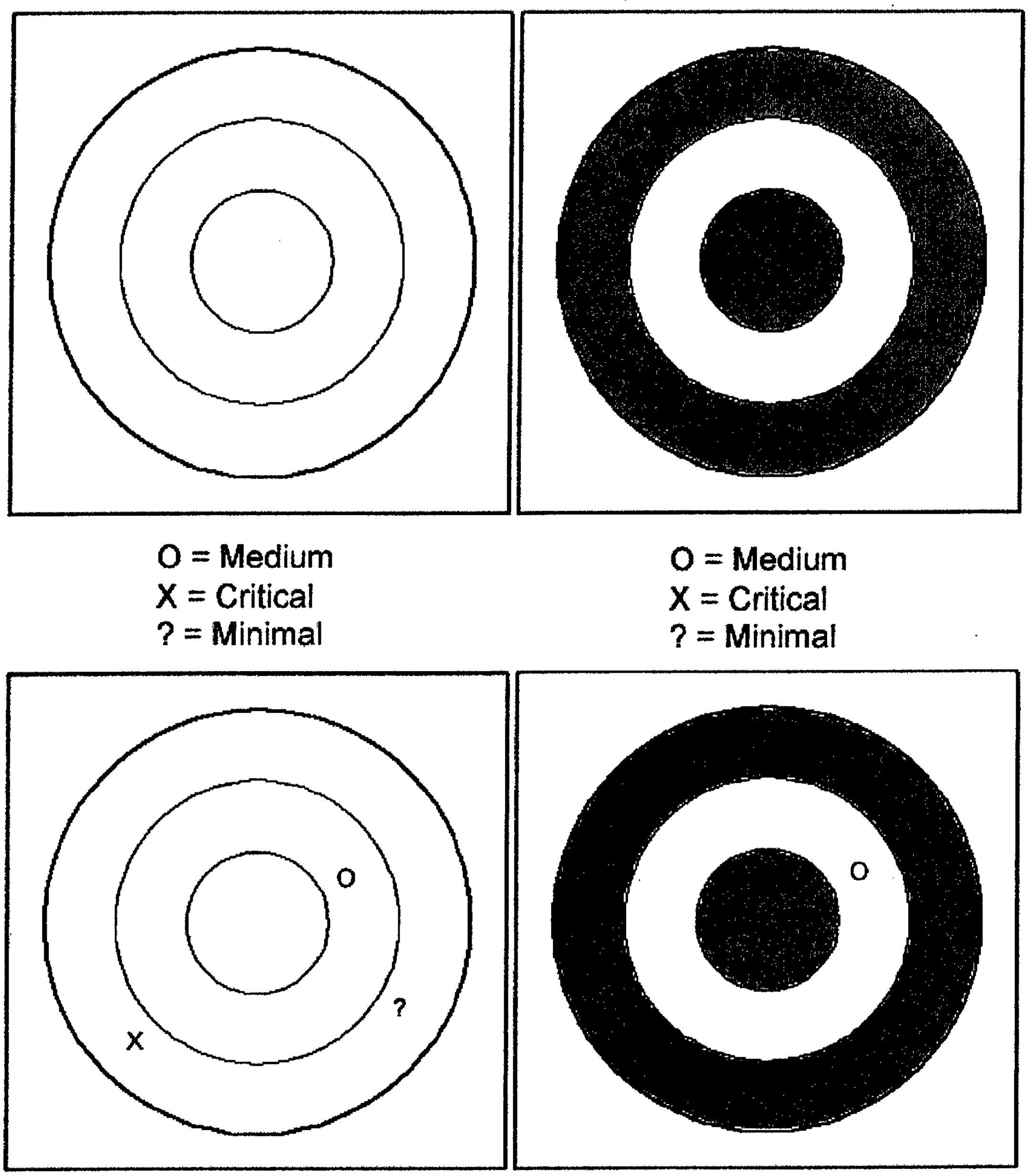

Figure 6-1: The RWR display: The upper images show the 3 rings that determine the criticality of response. The bottom images show an example of 3 objects which may appear on the RWR display. The object in the middle ring is a "MEDIUM THREAT" (O) and represents the greatest threat in this display. The other 2 objects are further away and pose less of a threat, even though the "X" is a critical threat.. The figure on the left shows the display uncolored and the image on the right shows the display colored to reflect the criticality of the rings (Green = alert, Yellow = danger, Red = critical).

The appropriate response by the subject will depend on the nature of the symbol that appears as well as where it appears. Three basic symbols will be used. The CRITICAL TARGET" symbol is an "X", the "MEDIUM TARGET" symbol is an "O" and the "MINIMAL TARGET" symbol is a "?". The symbols will all appear in the center of four quadrants in their respective areas of the display (i.e., they will not appear at the edges, so the subject does not have to make fine discriminations regarding which area they are in.)

The experimenter is able to specify the number of trials to be presented. Once this number has been selected, stimulus presentations are randomized over the entire test, so that each of the nine combinations (three areas X three symbols) appears an equal number of times (assuming the total number of trials selected is a multiple of 9).

Response manipulanda and requirements.

There are three possible responses for this test, and all will be made on the joystick. The required responses depend upon which combination of symbol and location is the most critical. The subject's task is to determine which symbol/location represents the greatest threat and press the button corresponding to the symbol ("0", "X", or "?").

The logic of the response requirements for this test is based on selecting the highest probable threat. If the "X" is in the center (red) zone, or is closer to it than either of the other symbols, it is the highest threat, and should be "attacked" (by pressing the designated button for the "X"). If either the "O" or "?" are in the center area, that symbol should be attacked. If both of the other two symbols are closer to the center zone than the "X", then one of them represents the highest threat, and the subject must apply different rules to determine which to "attack". If the "O" is closer to, or the same distance from center than the "?", then the subject should designate the "O" (as shown in figure 6-1). If the "?" is closer to the center than either the "X" or "O", then it represents the greatest threat. The test procedures are set up so that ambiguous combinations can not be presented, so there will always be a correct answer.

It is envisioned that subjects will require a reasonable amount of training on this task in order to reach a stable plateau. The actual amount will have to be determined during initial testing, but it should be sufficient to assure that the majority of potential subjects will reach plateau.

WHEN TO USE THIS TEST

This is a fairly complex test intended to probe the subject's long-term memory and logical reasoning skills -- all of which contribute to decision making ability. As such, the test is appropriate if the researcher is interested in questions of fairly high-level cognition during or after high-G exposure. Specifically, this test might be appropriate if interest is in the subject's ability to choose among options (where responses can not be highly automated), or where rapid information processing is required.

TRAINING REQUIREMENTS AND PLATEAU CRITERIA

Training and experience level on this test is very important. On the one hand, it is desirable to know that the subject has learned the general principles of the task, and is very clear on what the priorities and criteria are. On the other hand, it is not desirable to provide so much training that responses become automatic. The goal is to force the subject to make a reasoned choice on each trial. For these reasons, we recommend that training be carried out without trial-by-trial feedback, although that is a selectable option. Instead, the experimenter should monitor the correctness of the subject's responses over a block of, for example, ten trials. After each block, if the subject has made any errors, the experimenter should review the principles for decisions (not indicating to the subject what the errors were). This process should be carried out until the subject makes no errors on two consecutive blocks. At that time, it should be assumed that the subject has learned the principles, and no further training should be given. Similarly, when subjects are given this test in actual experiments, no trial-by-trial feedback should be given. Overall results can be given, but the subject should never be told what specific errors he or she made.

SET UP PROCEDURES FOR THIS TEST

Experimenter Options. The experimenter is free to present any number of trials in this test. Since the test is presented in a stand-alone mode, it runs rapidly and a large number of trials can be presented in a short time. Normally, it would be expected that 30 trials will be sufficient. However, if there is interest in seeing whether this skill degrades as a function of time-on-task, many more trials can be given (as long as no trial-by-trial feedback is given).

The selection of specific stimuli for each trial is done randomly and automatically by the test system. Constraints built into this system preclude the same stimulus pattern being presented twice in a row, or being presented more than twice in any 30 consecutive trials.

Anticipated Time to Administer This Test

The major time investment for this test is in the training phase. Once the subject understands the rules, actual presentation of 30 trials should not last longer than four minutes, and will probably be much shorter.

SUBJECT INSTRUCTIONS

Training Instructions. Since it is critically important that the subjects understand the logic and priorities of this test, these instructions assume great importance. As in other tests, the following instructions do not have to be presented verbatim, but the points contained in them should be covered. The subject should be asked to repeat the criteria for classification in his or her own words. If they appear to be having difficulty remembering the appropriate criteria, the experimenter might directly ask questions such as "What would you select if the "X" was in the middle ring, the "?" was in the middle ring, and the "O" was in the center?"

> IN THIS TEST, YOU WILL HAVE TO LEARN TO PRIORITIZE A "THREAT" AND TAKE ACTION AGAINST IT. YOU WILL SEE A SYMBOLIC REPRESENTATION OF A RADAR WARNING RECEIVER (RWR). THIS SIMULATION WILL DIFFER FROM A REAL RWR IN MANY WAYS. THREE LEVELS OF THREAT, REPRESENTED BY THREE SYMBOLS, WILL APPEAR ON THE SCREEN, AND THESE WILL APPEAR IN ANY OF THREE AREAS OF THE RWR. YOUR TASK IS TO DECIDE, AS RAPIDLY AS POSSIBLE, WHICH OF THE THREE REPRESENT THE GREATEST IMMEDIATE THREAT, AND PRESS A BUTTON

TO DESIGNATE THAT THREAT.

THE SYMBOLIC RWR WILL CONSIST OF A CIRCLE MADE UP OF THREE AREAS, OR "RINGS". (NOTE: the following instructions would be different if colored stimuli are not used.) THESE RINGS MAY BE COLORED. THE CENTER AREA IS DESIGNATED AS THE HIGHEST THREAT AREA (RED), THE MIDDLE RING IS DESIGNATED AS A MEDIUM THREAT AREA (YELLOW), AND THE OUTER RING IS DESIGNATED AS A LOW (BUT REAL) THREAT AREA (GREEN).

THREE SYMBOLS, REPRESENTING POTENTIAL ENEMY THREATS, CAN SUDDENLY APPEAR IN ANY OF THESE AREAS OF THE RWR. ONE SYMBOL, "X", DESIGNATES AN EXTREMELY DANGEROUS THREAT . ANOTHER SYMBOL, "O", DESIGNATES A LESS DANGEROUS THREAT. THE LAST SYMBOL, "?", DESIGNATES A PROBABLE THREAT, BUT WITH LESS IMMEDIATE DANGER THAN THE OTHERS.

THE RULES FOR ENGAGING THESE THREATS CONSTITUTE THE BASES FOR YOUR DECISIONS ABOUT WHICH TO SELECT AS THE MOST IMMEDIATE THREAT. (ALTHOUGH SOME OF THESE MAY SEEM UNREALISTIC, THE TEST REQUIRES THAT YOU LEARN AND FOLLOW THESE RULES.)

RULE 1. IF THE X APPEARS IN THE CENTER AREA, IT IS CLEARLY THE HIGHEST THREAT NO MATTER WHERE THE OTHERS MAY BE.

RULE 2. IF THE X IS IN THE SAME RING AS BOTH OF THE OTHER THREATS, OR IS CLOSER TO THE CENTER THAN BOTH OF THE OTHER THREATS, IT REPRESENTS THE HIGHEST THREAT.

RULE 3. IF THE X IS FURTHER AWAY FROM THE CENTER THAN EITHER OF THE OTHER TWO SYMBOLS, THEN ONE OF THEM REPRESENTS THE GREATEST THREAT, AND YOUR DECISION MUST DEPEND ON THE FOLLOWING RULES:

3A. IF THE "O" AND "?" ARE IN THE SAME AREA OF THE RWR, THE "O" REPRESENTS THE GREATEST THREAT.

3B. IF THE "O" IS IN THE CENTER OR MIDDLE RING OF THE RWR, AND THE "?" IS IN THE OUTER RING, THE "O" REPRESENTS THE GREATEST THREAT.

3C. IF THE "?" IS IN THE CENTER OR MIDDLE RING OF THE RWR, AND THE "O" IS IN THE OUTER RING, THE "?" REPRESENTS THE GREATEST THREAT.

ESSENTIALLY, YOUR TASK IS TO LOOK AT THE COMBINATION OF SYMBOL AND LOCATION, AND DECIDE WHICH REPRESENTS THE GREATEST THREAT

ACCORDING TO THE ABOVE RULES. ONCE YOU HAVE DECIDED, YOU WILL INDICATE YOUR DECISION BY PRESSING THE DESIGNATED BUTTON FOR THAT SYMBOL. REMEMBER THAT BOTH SPEED AND ACCURACY ARE IMPORTANT IN THIS TEST.

If these rules appear too difficult for some subjects, it would be permissible to use a few demonstration cards to illustrate them. However, to repeat, it is not desirable to have the subjects simply "memorize" the various stimulus configurations through practice.

Test Instructions

Since training is to be carried out until the subject is completely familiar with the test, no specific test instructions should be necessary. However, it is recommended that some re-familiarization trials be presented before actual testing is begun.

RECOMMENDED DATA ANALYSIS

Both accuracy and time scores will be recorded for this test. The most basic measure will be overall percent correct responses and reaction time for both correct and incorrect responses. These values are also calculated for each of the three categories of answer.

TEST NUMBER 7 - BASIC FLYING SKILLS

GENERAL TEST DESCRIPTION

The primary function of this test is to probe certain elementary skills required for safe and efficient flight. The flight scenarios that could be included in this test were constrained by the fact that centrifuge subjects are seldom pilots. Therefore, complex maneuvers could not be included. However, it was desirable in designing the test to include requirements for certain meta-cognitive skills. Therefore, a reasonably simple flying task was included that still required fairly high levels of information processing, including decision making, task multiplexing, problem analysis, etc. This task uses the "Flight-Performance Assessment Simulation System" (F-PASS) program as its basis.

The task of the subject in this test is to "fly" a navigation route, consisting of between two and six waypoints. He or she will do this by following a designated "script" of instructions detailing the route, speeds, and altitudes.

Although the above constitutes the basic function of this test, the test also serves as the framework for other tests. Collectively, these other tests will be referred to as the "F-PASS-related" tests. They include Test 8 (Gunsight Tracking), Test 9 (Situation Awareness), Test 10 (Unusual Attitude Recovery), Test 11 (Short-term Memory), and Test 12 (Visual Monitoring).

TECHNICAL SPECIFICATIONS OF THE TEST

A schematic of the navigation and flying task is shown in Figure 7-1. At test initiation, the aircraft will be located at Waypoint 1 (WP-1) heading north (360° magnetic), level at 15,000 ft altitude and 300 Knots airspeed. The initial task will be to maintain those flight parameters (airspeed and altitude) while flying to WP-2. The task can be complicated by a simulated crosswind (from 270° at 20 knots). WP-2 is 20 Nautical Miles (NM) from WP-1; and this leg should take about 3 minutes to complete.

Upon reaching WP-2, the navigation system will automatically shift its reference to the next waypoint (WP-3), located 120°, 7 NM from WP-2. At this point the subject is to perform a right turn, using approximately 30° of bank, to intercept and track the 120° course toward WP-3. An altitude of 15,000 ft and 300 Knots should be maintained on this leg. The time required for this leg will be about 1 minute.

In tracking directly to WP-3 consideration should be paid to any effect of wind. A heading (including crab angle) should be selected (by continual trial and error) that will cause the inbound radial to remain constant, as indicated by the #1 Needle on the HSI.

Upon reaching WP-3, the navigation system will automatically shift its reference to the next waypoint (WP-4), located 180°, 25 NM from WP-3. At this point the subject is to turn right, using approximately 30° of bank, to intercept the 180° course to WP-4. Approximately 10 NM after crossing WP-3, a synthetic voice command will instruct the subject to climb to and maintain 20,000 ft MSL. This climb should be performed at 350

Knots, initially using MIL power. Throttle and pitch angle should be adjusted as necessary to maintain 350 Knots during the climb, and to level at 20,000 ft at 350 Knots, while continuing to follow the intercept course to WP-4. Once reaching 20,000 ft., the subject should maintain this altitude and 350 Knots until reaching WP-4. This leg takes about 4 minutes.

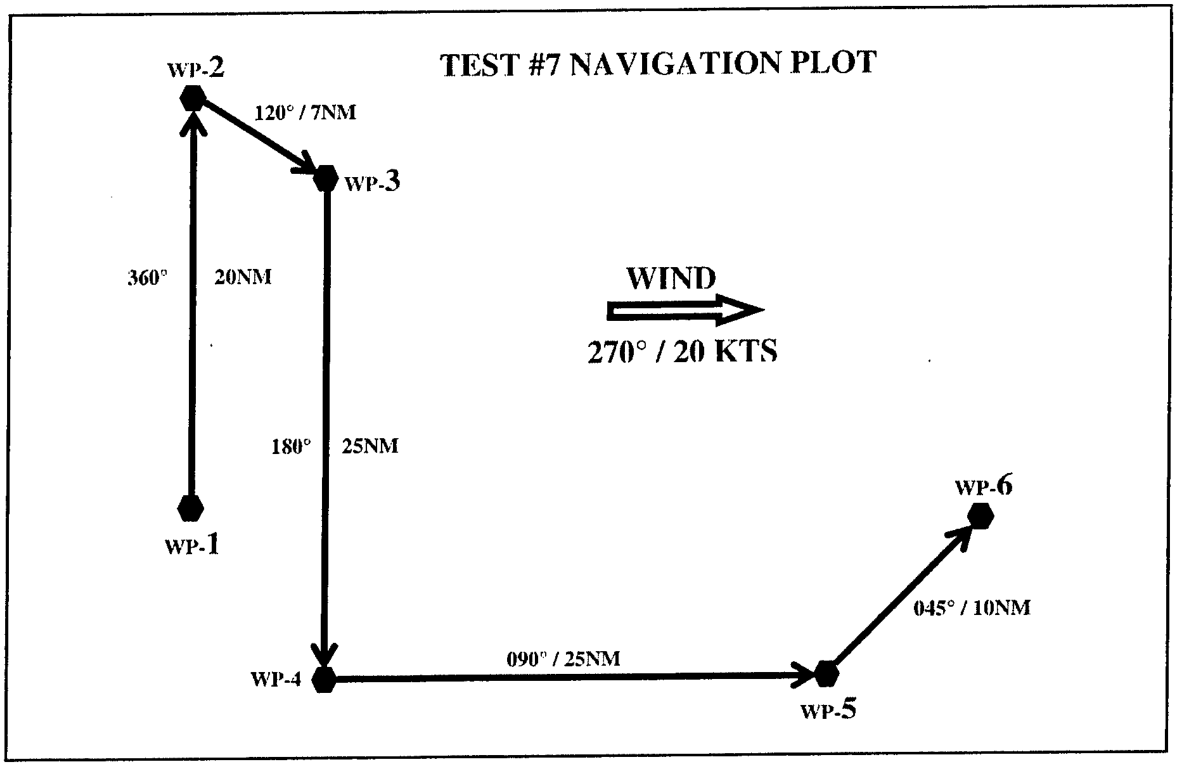

Figure 7-1: Basic Flying Skills Navigation/Flying Task.

Upon reaching WP-4, the navigation system will automatically shift its reference to the next waypoint (WP-5), located 090°, 25 NM from WP-4. At this point the subject is to turn left, using approximately 30° of bank, to intercept the 090° course to WP-5. About 10 NM prior to crossing WP-5 the subject will be instructed to reduce speed to 300 Knots, and descend to 12,000 ft. by the time WP-5 is reached. Speed should be 300 Knots at this time. The subject should use the throttle and speedbrakes as required to achieve this crossing restriction. This leg takes about 2.5 minutes to complete.

Upon reaching WP-5, the navigation system will automatically shift its reference to the next waypoint (WP-6), located 045°, 10 NM from WP-5. Immediately after passing WP-5, the subject will be instructed to "Continue descent to 8,000 ft. Maintain 250 knots below 10,000." At this point the subject is to continue descent to 8,000 ft while turning left, using approximately 30° of bank, to intercept 045° course to WP-6. The throttle should be used as required to slow to 250 Knots prior to reaching 10,000 ft. The subject should level at 8,000 ft, 250 Knots, and continue to WP-6. On reaching the CPA to WP-6 the test is terminated. This leg requires about 2 minutes to complete.

The entire test requires approximately 13 minutes. However, the experimenter can shorten this time by using fewer waypoints (e.g., only going to WP4). Similarly, the experimenter can lengthen the time by invoking a "Start Over" option. This option automatically directs the subject after WP6 to make the appropriate turn to return to WP1. The scenario is then repeated.

WHEN TO USE THIS TEST

This test provides a highly face-valid assessment of whether a variety of basic flying skills have been degraded. Overall, the assumption would be that if one sees degradation in these flying skills as a function of acceleration stress, more complex skills will also be degraded. Results of this test therefore provide a summary estimate of the effects of acceleration on flying proficiency.

In summary, if a single test probing the effects of acceleration on the broad concept of "flying skills" is all that can be employed, this test probably is the best of the G-PASS battery. On the other hand, if any of the F-PASS-related tests are to be used, this test will constitute the framework for them (see descriptions of these other tests below). If the primary focus of the investigation is one or more of the F-PASS-related tests, the specific navigation task should be difficult enough to provide a framework for the other tests but not so difficult as to degrade or interfere with performance on the other tests.

TRAINING REQUIREMENTS AND PLATEAU CRITERIA

Subjects must be highly trained on this task before any experiment can be run. For non-pilot subjects, this may take a considerable amount of time. However, since they are only training on one scenario, non-pilot subjects can become as proficient as pilots -- just not as quickly. As a first approximation, it would be estimated that an average of at least 25 iterations of the scenario would be required for each subject, but there could be wide variations around this number.

Since the entire set of data described below will be available off-line for the experimenter's inspection, it should be possible to decide when a reasonable plateau has been reached by a subject. The first criterion should be that the subject never misses a waypoint completely. If subjects can not perform at least five iterations of the scenario after extensive training without missing any waypoint, he or she probably should not be used with this test. More detailed inspection of the error and deviation measures should likewise reveal unusual variability from trial to trial. In this respect, the absolute value of the scores is not as important as the variability. Moderate performance is acceptable, as long as it is not too variable or showing noticeable improvement from trial to trial.

SET-UP PROCEDURES FOR THIS TEST

Experimenter Options. There are essentially no options except to decide how long the test should run. As explained above, the nominal duration is approximately 13 minutes. The experimenter can shorten this by electing to use fewer waypoints, or can lengthen it by repeating any or all of the waypoints.

Anticipated Time to Administer This Test. As noted above, the nominal time for this test is approximately 13 minutes, but this can be shortened or lengthened.

SUBJECT INSTRUCTIONS

Training Instructions. Test procedures and the navigation route should be briefed in detail prior to the first practice trial. Practice trials should be performed with immediate feedback and correction, until the subject feels comfortable with the specified procedures and performance stabilizes. Actual test instructions will be dependent on the experiment to be run.

RECOMMENDED DATA ANALYSIS

Data from the F-PASS scenarios does not include any summary statistics. All analyses are conducted off-line after the end of the session. Various tools are available for processing the raw data. Data handling tools process the data into Excel files that may be further manipulated and input into other programs such as statistical packages.

Specific data that are collected on the legs between waypoints are summarized below. Because of the unique requirements placed on the subject on different legs, there are some differences in what data are collected on each leg. In general, root mean square (RMS) measures are obtained for altitude, airspeed, and tracking deviations on each leg. Changes in these as a function of G exposure should provide a sensitive set of measures.

One leg of the scenario provides a unique challenge to the subject, and may have to be scored somewhat differently. Depending on how hard the subject turns at WP-2, navigation to WP-3 may require direct point-to-point navigation, rather than flying the specified path. If point-to-point navigation is required, then RMS variation in the bearing to WP-3 can be used as a measure of precision after the aircraft heading first equals or exceeds the bearing to WP-3 (that is once the aircraft is actually pointed toward the waypoint).

It should be noted that RMS altitudes are not scored during climbs and descents (legs 3-5) except at specific check points. RMS altitude is checked during level portions on these legs. These include the initial 10NM of leg 3, and once the aircraft first approaches to within 300 ft of 20,000 ft. In addition, on leg 4, the initial 15 NM level at 20,000 ft. is analyzed for RMS altitude. A point check should be made at WP-5 to see how close the subject is to specified parameters (12,000 ft MSL, 300 KIAS). This analysis typically is done off-line after data collection.

The subject should be slowing at his/her discretion from 300 KIAS to 250 KIAS on the final leg, so RMS airspeed is not calculated during the initial portion of that leg. Once the aircraft descends below 10,000 ft MSL, however, RMS airspeed becomes a valid measure again (250 KIAS reference) for the remainder of the test. Also, once the aircraft has descended to within 300 ft of 8,000 ft MSL on the final leg, RMS altitude (8,000 ft reference) is again calculated.

In summary, the following measures should be examined after analysis of each run:

Leg 1 (WP-1 – WP-2): RMS altitude (15,000 ft MSL)
RMS airspeed (300 KIAS)
RMS track deviation (360° bearing to WP-2)

Leg 2 (WP-2 – WP-3): RMS altitude (15,000 ft MSL)
RMS airspeed (300 KIAS)
RMS track deviation (120° bearing to WP-3)
OR
RMS bearing deviation to WP-3 as discussed above

Leg 3 (WP-3 – WP-4): RMS altitude (15,000 ft MSL for first 10NM, then 20,000 ft MSL after reaching altitude threshold)
RMS airspeed (300 KIAS for first 10NM, then 350 KIAS)
RMS track deviation (180° bearing to WP-4)

Leg 4 (WP-4 – WP-5): RMS altitude (20,000 ft MSL for first 15NM only)
Point altitude (12,000 ft MSL at WP-5)
RMS airspeed (350 KIAS for first 15NM only, then 300 KIAS)
Point airspeed (300 KIAS at WP-5)
RMS track deviation (090° bearing to WP-5)

Leg 5 (WP-5 – WP-6): RMS altitude (8,000 ft MSL after reaching altitude threshold)
RMS airspeed (250 KIAS at/below 10,000 ft MSL)
RMS track deviation (045° bearing to WP-6)

TEST NUMBER 8 - GUNSIGHT TRACKING

GENERAL TEST DESCRIPTION

This task will require the pilot to track a target, which is "flying" a predetermined path. The task will be able to be carried out in the centrifuge in either an open loop or closed loop manner, or it can be presented off-line. The obvious goal is to measure the pilot's visual-motor control ability. The various metrics to be obtained will serve as direct inputs into any simulation utilizing the cognitive model, or any systems model that might be utilized. As such, the metrics from this test constitute one of the most directly applicable inputs to various types of models (i.e., any decrement in the subjects tracking ability should directly reflect the individual's likely tracking response in the real world, without intervening assumptions).

In selecting specific stimulus movement and tracking dynamics for this task, a major consideration involves differences in the response characteristics between the Wright-Patterson and Brooks centrifuges. In the closed loop situation, the Wright-Patterson centrifuge is not capable of the same onset rates as the Brooks centrifuge. Therefore, if a closed loop tracking task is to be included, the movement of the tracked element needs to be different for the two centrifuges. At Wright-Patterson, the aero-model (F-PASS) had to be "damped" and the tracked element (target) had to make less abrupt movements. On the other hand, it was still be possible to require the subject to make control movements that produced extremely high-G turns for a given period of time. These requirements are not as critical at Brooks. The net result of these considerations is that no attempt has been made to have the closed loop "forcing functions" imposed by the target equivalent for the two centrifuges. Rather, the Brooks centrifuge will address questions of rapid onset rate (this capability has already been installed), while the Wright-Patterson centrifuge will address questions of slower onset rates and maneuvers requiring high G.

During this task, the subject will see a target aircraft appear. Instructions will indicate that at this point, the subject is to turn full attention to tracking and to keeping the target within the gunsight reticule. The display seen by the subject is the normal F-PASS F-16 display, but the trajectory (path) of the "target" is different for the two centrifuge applications (as detailed below). The gunsight is controlled by the subject, using the stick of the simulator, thus simulating moving one's own aircraft to bring it into firing range.

TECHNICAL SPECIFICATIONS OF THE TEST

Stimulus Characteristics. The basic aerodynamic model is an F-16. The stimulus display presented to the subject is an out-the-window view of the world with a heads-up display. The target reticule is the F-16 HUD gunsight cross. If a circle were drawn around the cross, it would subtend approximately 1.25 degrees of visual angle at a nominal viewing distance of 26 inches. The "target" is a moderately realistic depiction of an enemy aircraft flying at a fixed distance of approximately one-half mile from the subject. There are no orientation or glint cues provided as the target "maneuvers".

The target aircraft is presented as a high-contrast white figure against the blue-sky background.

This display is shown in Figure 8-1. The target aircraft will always remain at a fixed distance from the subject's aircraft (i.e., if the subject increases speed, the target will also appear to increase speed). The subject's task will be to maneuver in order to bring the moving "target" into the gunsight reticule (gunsight cross), and then to "fire" (hold down the "fire" button on the joystick) for the entire time the target is within the reticule.

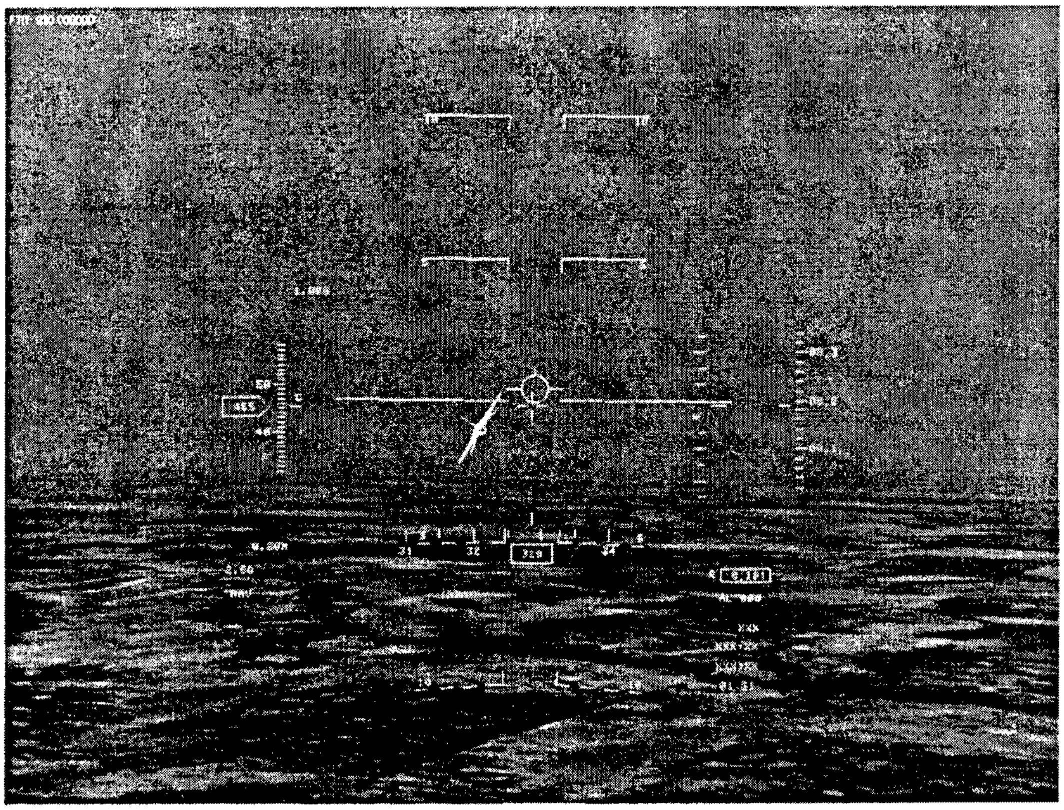

Figure 8-1. Gunsight Tracking view from the cockpit. The Tracked aircraft has just turned to the left.

Target motion is controlled by an independent program and is not dependent on the subject's responses. There essentially are three separate types of such programs provided. Two involve "canned" target scenarios, one for Wright-Patterson and one for Brooks. The parameters of these canned scenarios are presented in Table 8-1 below.

The Brooks scenario involves multiple high onset rates in the Gz axis, while the Wright-Patterson scenario involves slower onset rates (capable of being followed by the DES) for a wider variety of maneuvers. The third option is for users to create their own custom scenario.

Table 8-1: Scenario Parameters for Gunsight Tracking.

	FORCING FUNCTION	
FREQUENCIES	DURATIONS	AMPLITUDES
WRIGHT-PATTERSON CENTRIFUGE		
.5 Hz, .75 Hz., .1 Hz	5, 7, 10 sec	Sufficient to give 9 Gz
BROOKS CENTRIFUGE		
2 Hz, 1Hz, .5 Hz	3, 5, 7 sec.	Sufficient to give 7 Gz

Response Manipulanda. The control stick will be the only response mechanism utilized by the pilot for the tracking task itself. This control stick will activate the F-PASS aerodynamic model approximately the way a real aircraft would respond. In addition, the normal "fire" button will be used to indicate gun firing.

Subject Tasks in this Test. The primary task in this effort is, of course, to track the enemy target and keep it within the gun sight reticule as much as possible. This is carried out through movement of the control stick in the side and/or vertical dimensions. In the closed loop situation, these controlled movements produce appropriate acceleration forces for both centrifuges. In other words, the subject's control actions are linked to the centrifuge control mechanism (within, of course, the dynamic response capabilities of each centrifuge). In the open loop situation, the aircraft control movements are independent of the imposed G load on the person. In the off-line situation, there will, of course, be no changing acceleration force.

In addition to the tracking task, the subject will be instructed, as a secondary task, to press the "fire" button as soon as any portion of the target enters the gun site reticule. He or she will be instructed to depress the fire button for as long as the target or any portion of it is within the reticule. Instructions will indicate to the subject that this is an important, but secondary, task. It should be emphasized that the fire button should not be pressed until the subject is certain that the target is with the reticule.

WHEN TO USE THIS TEST

It is anticipated that this test will be used frequently, since it most resembles performance tests that have been used recently in the centrifuge. Its face validity, as well as the apparent (perhaps deceptive) ease with which it can be related to real-world flying makes it a logical choice for the experimenter wishing to answer a real-world flying concern.

However, it should be noted such extrapolation to actual flying requirements poses some problems. This essentially is a two dimensional tracking task, and does not involve the complexities of actual flight, which involve three dimensions, multi-tasking, mission planning, complex situation awareness requirements, etc. It should be kept in mind that this task addresses only one (important) aspect of the skills required of the pilot -- tracking. Therefore, broad conclusions or predictions of performance capability based only on this test should be avoided.

On the other hand, the fact that this test is part of an overall battery, and in fact is presented in the context of the Basic flying skills test (Test 7), can significantly extend its overall usefulness. Combined with measures of the other skills critical in combat flying, this test can make a significant contribution to an overall model of pilot performance. Therefore, a primary recommendation is that this test should only be used alone in special limited circumstances. Most often, it should be used in combination with Test 7, and with one or more tests from the G-PASS battery, where it can detect decrements in an important skill that can then be placed in context with other skills required for certain missions.

TRAINING REQUIREMENTS AND PLATEAU CRITERIA

This is a straightforward tracking task. As with most such tasks, learning can proceed for a considerable time before a true plateau is reached. However, a useful plateau level can be reached relatively quickly, to the point where subsequent continued improvement is very gradual and probably would not confound any experiment except one that was protracted over a very long time and involved a great many trials. Therefore, in general terms, a minimum of 10 practice sessions should be employed. The last few of these can then be inspected for variability or continued improvement. In most cases, it will be determined that additional practice is required, and obviously, this should be carried out until the experimenter has some evidence that the subject has reached a reasonable plateau.

SET UP PROCEDURES FOR THIS TEST

Experimenter Options. The experimenter should decide whether an existing scenario is appropriate, or whether he/she wishes to design a unique scenario. It should be remembered that when used as a stand-alone test, this is little more than a face valid version of a laboratory tracking task. Therefore, it should not be over-interpreted with respect to its direct predictability to the operational environment. For more complete assessment of the relevant cognitive processes, this test should be run as part of a scenario that includes the Basic Flying Skills Test (Test 7) and perhaps other non-flying tests.

Anticipated Time to Administer This Test

The duration of gunsight tracking is totally determined by the experimenter, based on the research question of interest. A "standard" default duration of 30 seconds can be chosen, although there is no specific reason that this is the standard. Depending on the research application, and whether this test is to be used in conjunction with the waypoint navigation of Test 7, tracking times from several seconds to several minutes might be selected.

SUBJECT INSTRUCTIONS

Training Instructions. Instructions for this test are straightforward if it is used in a stand-alone mode. The subject is simply instructed to acquire the target as quickly as possible by placing any part of it within the gunsight reticule. He/she is instructed that the target will try to "evade" their tracking, and they are to "follow" its movements as accurately as possible. The subject should also be told that he/she is to "fire" at the exact instant any part of the target enters the reticule, and to keep the fire button depressed until the target leaves the reticule completely. It should be emphasized that this simulation is unreal in that "firing on target" does not destroy it, but simply records when the subject knows that he/she is on the target.

Training can proceed as soon as the subject understands these instructions. Although there probably is continued improvement in tracking over a considerable time, for the present purposes an initial approach would be to give the subject ten 1-minute trials in order to assure familiarity with the controls and plant dynamics. Performance should be assessed after each trial, and further discussion and instruction should be given if it appears that the subject is having difficulty handling the task. Of course, if the experimenter is interested in very small changes in this skill, additional practice might be given until the subject appears to have reached plateau performance. Once plateau has been reached, the subject does not need further instructions before testing, except in the details of the specific experiment.

RECOMMENDED DATA ANALYSIS

Data from F-PASS scenarios does not include any summary statistics. All analyses are conducted off-line after the end of the session. Various tools are available for processing the raw data. Data handling tools process the data into Excel files that may be further manipulated and input into other programs such as statistical packages.

Tracking task. Data analysis for the tracking task is relatively straightforward. RMS and absolute error between the center of the target and the cross hairs' center is calculated for the duration of the run.

Firing tasks. The gunsight firing task probably represents a combination of attention allocation, vigilance, and visual motor reaction time. To encompass this range of functions, several types of analyses are carried out. First, the absolute latency of error in precisely firing when the target enters the reticule is calculated. This same measure is taken for the latency error of when the target leaves the reticule. The number of instances in which the subject fires more than one-half second before the target reaches the reticule ("anticipatory response") is calculated, as well as the number of "misses" (times that the subject fails to fire when a target was within the reticule). Each of the measurements includes time-tagging and/or G-load tagging, so that the researcher will be able to analyze these data in a variety of ways. The standard analysis provided, however, is an overall summary of the entire scenario or trial, as well as summary for each segment into which the scenario was divided.

TEST NUMBER 9 - SITUATION AWARENESS

GENERAL TEST DESCRIPTION

Situation awareness (SA) is arguably one of the most important skills that a pilot must maintain for safe and efficient flight. Yet, it is perhaps the least studied skill that can be affected by acceleration forces. Significant reasons for this are not only the difficulty of measuring the skill, but the problem of even defining it. SA is a complex construct involving many subsidiary skills. As such, it defies easy classification according to current models of cognition. In attempting to develop measures of situation awareness in the acceleration environment, it was necessary to explore a large number of proposed definitions and measurement approaches, unlike many of the other measures in the F-PASS system. These explorations were presented in some detail in the final report for an earlier Air Force SBIR Phase I effort (Final Contractor's Report, Small Business Innovation Research Contract titled Measurement And Modeling Of Human Performance Under Differing G Conditions: 1. Design Of The "G-Performance Assessment Simulation System" (G-Pass) And The "G-Tool To Optimize Performance" (G-Top), March, 2001).

SA test procedures incorporated into G-PASS.

The general orientation in selecting SA metrics for G-PASS was to include a range of techniques that probed as many information processing components as possible. Further, the concept was to develop a set of metrics that could be "embedded" into the basic flight simulation test (Test 7, Basic Flying Skills). These metrics were conceptualized as relatively discrete measures, each of which would contribute a different kind of information about the individual's SA at the time of measurement. These are discussed in some detail under the heading "Set Up Procedures for This Test" below. They would then provide a multi-dimensional description of the person's state of SA (which, after all, is a multiply determined construct). This description would be based on which capabilities he or she can demonstrate, and the degree to which each one is demonstrated. In other words, the intent was to provide a measurement tool that is able to define the profile of an individual's SA.

TECHNICAL SPECIFICATIONS OF THE TEST

Stimulus procedures. The basic approach to presenting stimuli for this test utilizes the "probe" techniques described above. In this technique, a question appears on the screen at specific points in the scenario, after the screen is blanked. The points at which a given question may appear are constrained by the software to assure that the question is appropriate in that situation. The actual presentation of the question is straightforward. At the selected point in the scenario, the screen simply blanks, and a short question is presented. A blue background with white lettering for the question is used.

When the screen is blanked for this test, the experimenter must determine what happens to the ongoing aero model during the blanked period. In the simplest case, when the screen returns after the subject's response to the question, the aircraft would be in exactly the same position it was when blanking occurred. This is the default option for the experimenter. However, the experimenter may wish to introduce an "unusual attitude" at this point. The test procedures would then be as described for Test 10 (Unusual Attitudes Test).

The questions asked should always require a YES / NO or TRUE / FALSE response. The responses to the various situation awareness questions need to be evaluated based on the conditions in the scenario. The response manipulanda for the subject are simple positive (yes/true) or negative (no/false) buttons on the joystick.

WHEN TO USE THIS TEST

Questions about pilot's SA come into play whenever there is suspicion of even mild cerebral hypoxia due to acceleration. Because the G-PASS System provides a range of SA measures, it should be sensitive to every type of SA decrement described in the literature.

The experimenter must be aware of the fact that the presence of too many SA probes are presented in a given scenario may "prime" the subject to search environmental situations in an unrealistic way. It is up to the experimenter to design the experiment in such a way as to minimize this, while collecting the greatest amount of data upon which to make a determination.

TRAINING REQUIREMENTS AND PLATEAU CRITERIA

Training requirements for this test will vary depending on the type and difficulty of the questions selected by the experimenter. In any case, however, it is desirable not to use the exact questions during training that will be used in testing. Rather, a "parallel" set of training questions might be generated. For instance, if there will be a question of the altitude the person is currently flying, the training question might be of the same type, but given at a radically different altitude. In addition, one might require a "yes" answer, and the other a "no".

The basic goal of training is not to achieve a perfect score, or even to be very good at the answers. It is to assure the subject understands the requirements, and that he or she is performing at their best level consistently. Therefore, it should seldom be necessary to give more than ten training questions unless inspection reveals consistently wrong answers or some other anomaly in the subject's answer pattern (e.g., each correct answer followed by an incorrect).

SET UP PROCEDURES FOR THIS TEST

Experimenter Options.

The first decision involves whether to probe all sub-categories of SA possible within G-PASS, or to focus on one particular category. The types of questions are described briefly below. Since the experimenter may modify the basic scenario presented in Test 7 (Basic Flying Skills), questions will have to be generated that are appropriate to the scenario.

Measure type 1. Environmental awareness.

Virtually all information-processing theories agree that appropriate registration of sensory conditions provides the basic foundation for later processing. In the case of SA metrics, this must be taken to include not only basic sensory registration, but some level of conscious awareness of the sensory environment. Stated most simplistically, this type of SA processing says that the person must be taking in the relevant aspects of the environment and, at some level must be "aware" of that environment. This is similar to what Endsley (1990) describes as "level 1" situation awareness. In the present case, it is proposed that this type of SA incorporates processing beyond the iconic and echoic stages in that some degree of "awareness" must be present. It should be noted that this awareness need not be in the forefront of consciousness. Rather, the criterion established for this type of awareness is simply that the information is retrievable. In other words, either simultaneously with its occurrence or subsequently, the person can remember and report the information concerning the immediate environment.

In terms of this type of awareness, it is hypothesized that the person should be able to report on the existence of significant aspects of the environment. The goal here is simply to determine whether the person is able to retrieve sensory input information from short-term memory. No attempt is made to elicit precise location information or complex interpretation of the data, and no projection into the future is required. Thus, this level of probe is intended simply to measure the person's range of "awareness" of the environmental conditions. The information requested simply involves whether a given situation, event, or object is present or not. Some examples of this type of question are: 1) At 900 MSL, ask: "YOU ARE NOW ABOVE 800 FEET", and 2) At 9 min. into the mission, ask: "YOU ARE LESS THAN 8 MINUTES INTO THIS MISSION", and 3) "YOUR HEADING IS NOW 180".

Measure type 2. Awareness of future actions.

In this case, the questions asked of the operator during the blanked period do not simply refer to the presence or absence of an environmental condition, but rather request information about an activity to be carried out in the future. In other words, the operator is not simply queried about whether an object or condition exists, but is asked to anticipate an event or condition that will happen later. Although this and the previously described measure appear to share a great deal in common, it is argued that they actually measure different levels of SA. At very least, responding correctly to questions involving future action requires an ability to "project" events based on current conditions. Thus, it would appear that this type of awareness requires considerably more working memory capacity than simply reporting whether the object or condition was present. In practical terms, this type of probe should be operationally relevant in those situations where the individual might become pre-occupied with the current task to the extent that future actions are jeopardized. The actual measurement of this level of SA is virtually identical to that described for SA Measure type 1. The only difference is that questions probe what the pilot has been instructed to do in the future.

Some examples of this type of question are: 1) At 15,000 MSL, ask: "YOU ARE TO TURN LEFT WHEN YOU REACH WP2", 2) Immediately after WP2 has been entered, ask: "YOU WILL MAKE AN ALTITUDE CHANGE BEFORE REACHING WP3", and 3) After reaching WP5, ask: "YOU WILL BE REQUIRED TO MAINTAIN 350 KNOTS THROUGHOUT YOUR NEXT DESCENT".

Measure type 3.

Awareness of integrated/projected information.

This level of SA encompasses the subject's ability to report considerably more dynamic aspects of the stimulus environment than simple existence of objects or conditions, or programmed future action. Specifically, the probes in this measure are designed to determine whether the person is capable of reporting information that is "derivative" in nature. In this context, the term "derivative" is defined as requiring the integration of a number of sensory/perceptual elements into a hypothesis about a present or future state of the environment. In other words, this level of SA results in "information" (or a belief) that a state exists, or is about to occur, in the environment which cannot be confirmed by the information available in the environment at this moment in time. It is an extrapolation or inference based not only on the data immediately available, but also on what has gone on previously, and the operator's expectations about what will go on in the future.

The general concept of this level of SA is based on the assumption that the subject, at various levels of SA, progresses from a simple awareness of "what is" or "what will certainly be", to "what might be". In the previous assessment techniques, probes have determined whether the person knows that certain environmental objects exist, and what he or she is supposed to do in the future. In the present level of SA, the probe is directed to determining whether the subject knows what future conditions will exist given what is happening *now*. In other words, given certain assumptions, what will my present state cause to happen in the future? At this stage, interest is in whether the subject can predict these future events at a relatively simplistic level. Still, it should be noted that this level of SA involves relatively advanced cognitive functioning, and therefore will require somewhat more sophisticated "training" of the person in the sense it requires that the person have extensive experience with the specific predictions unique to the flight environment.

Two types of questions are used under this general level of SA: specific event projections, and more complex "derivative" event projections. The first type is similar to the "projection" probes described by Endsley (1991b). The probe questions deal with projections of specific events into the future. For instance, the question might be "DO YOU HAVE LESS THAN 1 MINUTE LEFT BEFORE ARRIVING AT WP3?"

The second category of question under this general technique involves a more complex derivative awareness by the subject. Interviews with pilot consultants revealed that there are certain cognitive "bases of flight operations" which are critical to combat success. A prime example of such a basis can be termed "perception of the enemy's plane of operation." In air-to-air combat, it is critical to maintain awareness of the plane described by the enemy aircraft's current linear momentum (Shaw, 1985). In effect, in a dynamic engagement between aircraft, the "horizontal" plane, which is normally represented by the earth's horizon, changes every time an enemy aircraft makes a maneuver (and the pursuit aircraft responds to that maneuver). At one moment, the enemy may be flying or turning in a plane that is completely parallel to the horizon. In the next instant, the enemy may enter a diving turn in which the plane of operation now changes to a 45-degree angle relative to the horizon. It is incumbent on the pilot to be aware of the enemy's plane of operation at all times in order to carry out a responsive maneuver. An example of this type of question might be "IS A 60 DEGREE BANK ANGLE THE BEST WAY

TO INTERCEPT THE COURSE TO WP5?" Other general examples of questions that could be generated in these categories are fuel management and projections of future actions.

Of course, this type of question involves higher level processing, as well as extensive training. As such, it will probably only be useful for unique, high-priority experiments in the centrifuge. However, the capability to obtain this information is available if the experimenter desires it.

Structuring Scenarios and SA Events

As noted above, because this test will be used in a wide range of situations, it is not feasible to provide an extensive list of "canned" SA questions. Therefore, it is up to the experimenter to decide how many events should be included in a scenario, and which levels of SA should be tested. The actual SA questions can then be generated, using the above examples as guides. Again, however, the experimenter must assure that a given SA question is appropriate for the actual condition being experienced by the subject (e.g., not asking about a rate of turn when the subject is flying straight and level). It is generally not recommended that the same scenario be repeated many times for a given subject. Design of any particular scenario immediately defines the number of SA events that can be incorporated in that scenario. If the experimenter decides that a designed scenario does not contain enough events, or that it does not contain the correct "mix" of SA types, the scenario can be re-designed to incorporate more desired events.

Anticipated Time to Administer This Test.

The primarily determinate of timing of this test is the number of SA questions and the portion of the basic scenario where they are presented. Scenarios may range from a few minutes up to 13 minutes, and even longer. It is unlikely that any measure of SA can be determined for a very short time period such as would be involved in rapid onset high-G exposures. Therefore, it would be anticipated that these measures would be appropriate for either low-G sustained exposures or after one or more high G exposures. We would not anticipate that useful measures can be obtained in any less than one minute on this test.

SUBJECT INSTRUCTIONS

Training Instructions. The researcher typically will not want to directly inform the subject that this is a test of situation awareness. However, the subject should be informed of the general response requirements, and should be able to anticipate that questions may appear on the screen. The subjects should also be made aware that at various times, things "could go wrong". Again, while it is not necessary to utilize the exact recommendations noted below, the major points in these instructions should be incorporated into the training instructions.

The first set of instructions that should be given are those described under Test 7 for the Basic Flying Scenario. After those instructions have been given, the following instructions might be presented:

> IN ADDITION TO THE BASIC FLYING TASK, YOU MAY ALSO BE ASKED QUESTIONS OR GIVEN STETEMENTS CONCERNING THE POSITION,

SURROUNDING ENVIRONMENT, AND/OR ANTICIPATED EVENTS IN THE SCENARIO. THESE WILL APPEAR ON THE SCREEN OCCASIONALLY DURING THE COURSE OF FLYING THE SCENARIO. THE FLIGHT SIMULATION WILL BE SUSPENDED DURING THE TIME THAT THE QUESTION IS ON THE SCREEN. ALL QUESTIONS OR STETEMENTS WILL REQUIRE A YES OR NO (TRUE OR FALSE) ANSWER. YOU DO NOT HAVE TO ANSWER AS RAPIDLY AS POSSIBLE, BUT YOU SHOULD NOT TAKE AN EXCESSIVE AMOUNT OF TIME TO CONSIDER YOUR ANSWER. AS SOON AS YOU RESPOND, THE FLIGHT SIMULATION WILL REAPPEAR ON THE SCREEN, AND YOU ARE TO CONTINUE AS IF THERE WAS NO INTERRUPTION.

(If an unusual attitude test is to be incorporated into this test, the additional instructions for unusual attitude contained in test 10 should be inserted here.)

Test Instructions. Since it recommended that the subject be given at least one training scenario on this test, it is assumed that the subject will be familiar with basic procedures and no different testing instructions are specified. The experimenter should be aware that there are unique conditions that must be explained to the subject (e.g., type of G exposure, duration of exposure, when the test will appear, the possibility of unusual attitudes, etc.). These must be added to the general instructions for the test.

RECOMMENDED DATA ANALYSIS

Data from F-PASS scenarios does not include any summary statistics. All analyses are conducted off-line after the end of the session. Various tools are available for processing the raw data. Data handling tools process the data into Excel files that may be further manipulated and input into other programs such as statistical packages.

The simplest form of data analysis for this test is the percent correct answers to the probe questions. In addition, these summary data are broken out for each of the three types of probe question, allowing the possibility of looking at whether different levels of information processing were affected by the acceleration force.

As a further analysis possibility, Eubanks and Killeen (1983) and Amburn (1994) have suggested that probes structured with "yes-no" responses permit information-theoretic analyses. Since each response reflects a "positive hit" (a correct yes answer), a "negative hit" (a correct no answer), a "positive miss" (an incorrect no answer), or "false alarm" (an incorrect yes answer), the data lend themselves to a 2-by-2 matrix. From this, following Kantowitz and Sorkin (1983), the sensitivity of the subject (d') can be calculated for the given experimental condition. In other words, standard information theoretic measures can be calculated. If desired, even entire receiver-operating-characteristic (ROC) curves could be determined for a series of experimental conditions to account for other sources of variance than SA. The "sensitivity" of the operator reflects his or her ability to detect an environmental condition. Fracker (1991) recommends this approach as "...an empirical and an intuitively reasonable measure of awareness for a particular kind of event".

TEST NUMBER 10 - UNUSUAL ATTITUDE RECOVERY

GENERAL TEST DESCRIPTION

Although there is some debate in the literature, it is more or less generally agreed that unusual attitude (UA) recovery provides a measure of one type (or a subset) of "situation awareness" (SA). The speed and appropriateness of a pilot's ability to regain straight and level flight when, for whatever reason, the aircraft gets into an attitude that is not desirable or appropriate appears to probe the immediacy of his or her perception of the situation, integration of this situation with immediate past situations and goals, and implementation of well-learned "schemas" or "scripts" for responding to the unusual situation. In view of this, it appears that this type of metric could contribute to the "working memory" portion of the cognitive model by allowing us to estimate changes in the pilot's mental model of the situation during or after acceleration exposure. (Of course, this does not reveal what the mental model was.) However, combined with other measures of SA this could provide meaningful and face valid inputs into the model. This task clearly involves long-term memory functions integrated with working memory with vestibular integrity required in real world situations.

In all UAs, the aircraft will be in an attitude which, 1) could not have been anticipated by the pilot, 2) represents a dangerous condition of the aircraft. The required response will be to recover from the unusual attitude as quickly as possible. Measures of speed and appropriate response are collected.

TECHNICAL SPECIFICATIONS OF THE TEST

This task will be carried out using the F-16 HUD display. UAs can be presented in two ways.

1) Following a Situational Awareness (SA) question. Whenever the subject has been presented with an SA a question (see Test 9), the experimenter will have the option of presenting either an unusual attitude or a "normal" flight condition. Upon answering the SA question, the flight simulation screen returns. If a UA has been specified, the aircraft will appear in an unusual attitude (as if the aircraft had deviated while the question was being answered

2) The experimenter may elect to present one or more UAs at selected points in the Basic Flying Scenario. In this case, the simulation will "suddenly" be in an unusual attitude when the specified part of the scenario is reached.

The pilot's task is to recover to straight and level flight (+ or – 5 degrees bank, + or – 3 degrees of pitch) as soon as they detect that they are in an unusual attitude. The table below lists the default set of UAs for this test.

Table 10-1. Default set of Unusual Attitudes

Nose high (15°)
Nose low (15°)
Rt. 45°, 0° pitch
Lt. 45°, 0° pitch
Rt. 45°, +15° pitch
Lt. 45°, +15° pitch
Rt. 45°, -15° pitch
Lt. 45°, -15° pitch
Rt. 90°, 0° pitch
Lt. 90°, 0° pitch
Rt. 90°, +15° pitch
Lt. 90°, +15° pitch
Rt. 90°, -15° pitch
Lt. 90°, -15° pitch
Rt. 135°, 0° pitch
Lt. 135°, 0° pitch
Rt. 135°, +15° pitch
Lt. 135°, +15° pitch
Rt. 135°, -15° pitch
Lt. 135°, -15° pitch
Inverted, 0° pitch
Inverted, +15° pitch
Inverted, -15° pitch

WHEN TO USE THIS TEST

As noted above, the unusual attitudes test is probably a subset of the Situation Awareness test (Test 9). As such, it should be considered for use whenever the experimenter is interested in a general area of situation awareness.

It must be noted that the UA measures, unlike the SA measures, requires a considerable degree of performance sophistication on the part of the subject. In fact, it is highly desirable that the subject be practiced on the unusual attitudes almost to the point of "automaticity". This means that the UA test cannot be used unless the subjects can undergo extended training. It is not recommended that the test be used with inadequately trained subjects, since the data will not only be too variable, but the desired construct will not really be tested.

On the other hand, in any situation where adequate training can be carried out, this measure provides a sophisticated probe of higher cognitive functions. With adequate training, the measure provides an index of the subject's decrement in automatic functions as a result of acceleration stress. Such automatic functions are required for a large variety of flight performance reactions, especially in fighter aircraft. Further, there is a considerable degree of working memory involved in this test. Results from this probe could be extrapolated to a large number of operational functions in a fighter aircraft.

It is also possible to use the UA test to simply examine a series of UAs that are presented one after another. This allows the possibility for testing the effects of acceleration on UA recovery independent of other flying activities.

TRAINING REQUIREMENTS AND PLATEAU CRITERIA

As noted above, performance on this test requires a great deal of sophistication on the part of the subject. Actual pilots probably would demonstrate skilled performance with a few practice trials. However, non-pilots will require at least 30 practice trials to become even reasonably proficient at the task. In some cases, this may be enough for a specific experiment. However, it should be noted that in this case, the construct of "automaticity" is not being tested, and positive results should be interpreted cautiously as far as their applicability to real-world piloting.

If extensive practice can be given, it is extremely desirable to do so. The criterion for "automatic behavior" involves not only good performance in the entire recovery, but perhaps is most noticeable in the speed with which the subject initiates the first appropriate action. Subjects who have "learned" the task but have not yet automated it will tend to be slower in deciding what to do. When the experimenter sees a rapid and consistent initiation of the first appropriate action, it is likely that the skill has been automated.

SET UP PROCEDURES FOR THIS TEST

Generally a specific UA should not be requested more than two times in a row. Such repetitive presentations are permitted, but it is important that the experimenter be made aware that they are occurring.

The experimenter must be aware of the aircraft position when a SA/UA combination is requested. There may be some conditions in which a UA recovery is more difficult or impossible (e.g., at too low an altitude). The experimenter must be sure that the starting aircraft position is adequate to allow recovery from whatever UA is selected.

Experimenter Options. The experimenter has three options for this test: 1) whether to present a situation awareness question followed by an unusual attitude, 2) whether to present a series of UAs, and 3) how many UAs to present.

In most situations, one would not present the UA after every situation awareness question. If that were done, the subject would become so used to the pairing that the two tests might merge into one, confounding interpretation. The target split (if this test is used) should be 50% of the questions followed by an unusual attitude, and 50% not followed by one, in random order. It is recognized, however, that this split may not be feasible in all experimental situations. In that case, the experimenter must decide on a feasible split, and adjust interpretation of the test accordingly.

The UAs are randomly selected for presentation on each trial with no one UA presented more than two times in succession. The various UAs are designed to be close to each other in difficulty (at least for experienced individuals). Therefore, a random selection among the available UAs is sufficient.

The question of how many UAs are necessary to provide a sensitive measure of decrement is problematical. In most experiments on the centrifuge, it will probably not be possible to obtain a large number of UA samples, due to time and exposure constraints. One may be limited to anywhere from one to ten samples in some cases. Typically, this would not be expected to yield statistically sensitive results. A mitigating factor, however, is that it is likely that if decrements really exist during or after acceleration, they will be large. In fact, scoring of the test is such that only rather large decrements are considered. Therefore, if a decrement is found on this test, it can be considered significant even with a small number of trials. In any case, it is up to the experimenter to decide how many samples can be obtained, and to in interpret the results accordingly.

Anticipated Time to Administer This Test. A single UA trial should not last more than 45 seconds. In fact, a default "timeout" command at 45 seconds has been incorporated. If the subject has not achieved straight and level flight in that time, the aircraft is automatically brought into that condition, and the scoring assumes that the subject failed. Typically, a trial should last between 15 and 30 seconds. A trial ends when the subject has regained straight and level flight (+ or – 5 degrees bank, + or – 3 degrees of pitch).

SUBJECT INSTRUCTIONS

Training Instructions. Training is critical on this task. The basic concept of the task is to probe well-learned, virtually automatic functions. Therefore, it would make little sense to use this task with subjects who are poorly trained. It should be noted that there is no problem with over-training subjects on this task. Given these conditions, it is recommended that a pool of subjects be trained continuously over a long period of time on the specific unusual attitudes to be used. We would recommend no fewer than 30 complete training sessions involving each of the unusual attitudes be given. More would be desirable. These should be carried out with individual feedback and correction for each trial. Sessions should be distributed such that no more than five repetitions of each UA condition are presented in one sitting, and sessions should be spaced at least one week apart. Therefore, a minimum of six weeks training is recommended on this test.

Since training on this test is critical and involves individual feedback, no specific training dialogue is presented. It is assumed that the experimenter is familiar enough with the recovery procedures that appropriate training feedback can be provided.

In the rare case that adequate training cannot be provided, and the experimenter still wishes to use this test, extreme caution and interpretation of results is recommended. If the subject has not been adequately trained, then the construct being tested is not automaticity or long-term memory, but rather a superficial following of directions. While there may be instances where this is desirable, they should be the exception rather than the norm.

Test Instructions. Since training has been so extensive in this test, normally the subject will not need additional test instructions to understand how to respond the unusual attitudes. However, it must be assured that the subject understands that unusual attitudes may occur at any time during the flight scenario performance. It is probably not necessary to specifically inform the subject that an unusual attitude will or will not follow questions concerning situation awareness. They will soon come to that conclusion.

Instead, a general instruction indicating that unusual attitudes may occur unexpectedly during the performance of the flight task should be sufficient. The subject should however, be advised that when an unusual attitude occurs, this takes priority over any other task, and constitutes a dangerous situation that must be attended to immediately.

Other than this, care should be taken to assure that the subject understands that the flight simulation task, the situation awareness task, and the unusual attitude task, may be intertwined. No specific instruction in this respect is probably necessary, although the experimenter should be confident that none of the three tasks will constitute a surprise to the subject.

RECOMMENDED DATA ANALYSIS

Data from F-PASS scenarios does not include any summary statistics. All analyses are conducted off-line after the end of the session. Various tools are available for processing the raw data. Data handling tools process the data into Excel files that may be further manipulated and input into other programs such as statistical packages.

The basic metric in this test is the time from onset of the UA to the achievement of the recovery criteria described above. To determine this, the basic aircraft position in space is recorded at 30 times per second. In addition, the timing and direction of the pilot's initial (and subsequent) control input with regard to pitch, roll, throttle, and speed brakes are all captured.

It should be noted that one confounding variable in interpreting this test is if different subjects develop different strategies than those presented as "optimal". Interest is not in the particular strategy used, but rather in any change in strategy that is not productive (i.e., that produces a decrement). Therefore, in almost all situations, it is important to compare each subject's performance in a "pre-post" design (each subject as his or her own control).

TEST NUMBER 11 - SHORT-TERM MEMORY WITH DISTRACTIONS

GENERAL TEST DESCRIPTION

The purpose of this test is to probe the general efficiency of "short-term" memory processes, and their susceptibility to disruption by acceleration forces. The term short-term memory is used here in a narrow sense in that the goal is to measure the subject's ability to take information in, to hold it in memory for some period of time while other events are happening, and then to act on it. The test will instruct the subject to carry out some action (the item to be remembered) at a future time. While waiting for the response time, some intervening (interfering) activity will be required of the subject. Interest is in seeing whether the subject remembers to carry out the action, and whether the information was distorted during the intervening time. The researcher will have the capability of varying both the time interval during which the information must be stored, the type of information processing that will be required, and the general nature of intervening activity.

TECHNICAL SPECIFICATIONS OF THE TEST

This test will typically be presented while flying the Basic Flying Skills Scenario (Test 7). Instructions to the subject are presented verbally through headphones. While other modes of stimulus presentation may be designed by the experimenter (e.g., messages appearing on the screen), these are not currently designed into this test. With the creation of proper verbal input files, the experimenter may manually insert any desired instruction to the subject at any point in the scenario. In order to assist in standardizing the procedure, however, several representative "canned" instructions involving radio frequency changes, squawking ID, change altimeter setting, make radio call, etc. are available.

Responses to this test are made using the stick and throttle. The experimenter may develop an alternative response medium if desired. For instance, the experimenter might utilize verbal responses during high G. This can be done through the existing intercom system, but the response would have to be monitored and scored on-line by an investigator. Timing accuracy is not a primary concern in this task, and response timing or on-line experimenter scoring is probably sufficient. For the stick/throttle responses, a designated button is used to represent single input responses such as acknowledging passing a given altitude, or squawking ID. More complex responses are made through a combination of button presses.

As noted above, it is envisioned that this test will be embedded into the flight scenario described in test number 7. Depending on the purposes of the experiment, the experimenter will be expected to select a scenario in which the short-term memory functions to be measured are appropriate. If, for instance, the experimenter wishes to determine short-term memory processing <u>during</u> a given G exposure, a flight scenario that would permit a short-term memory probe of less than 20 seconds would be selected. On the other hand, if the experimenter was interested in determining the effect of multiple prior G exposures on a subject's performance sometime after those exposures, a longer scenario could be selected that would permit a delay of up to 20 minutes. We anticipate that the investigator will most often be interested in two durations of memory delay. Immediate short-term memory of less than 20 seconds, and short-term memory proper of more then 20 minutes.

WHEN TO USE THIS TEST

Short term memory involves considerable working memory function, and therefore is probably localized in the frontal and/or prefrontal areas of the cortex. As such, it is very likely to be affected by G forces high enough to cause cerebral anoxia. Questions concerning the degree of acceleration, as well as its timing with respect to their effect on short term memory will certainly call for the use of this test. Unlike laboratory synthetic tests of short term memory, this test embeds the probe into operationally meaningful situations. Therefore, it will be of interest not only to define the parameters of G effects on this function, but to compare results found with this test to those found in more isolated laboratory conditions.

SET UP PROCEDURES FOR THIS TEST

With respect to the type of information processing to be carried out during the delay period, a range of information complexity that must be retained over the delay should be incorporated. At the simplest level, the subject would be asked to perform an action at some specified time in the future based either on time or on noticing an event. For instance, the subject may be instructed to initiate a call in 20 seconds, or to report reaching a given altitude. At a somewhat more complex level, the subject will would be required to remember between three and seven alphanumeric characters, such as entering a radio frequency, at a given time in the future. At the most complex level, the subject may be asked to remember a set of complex instructions, and then to carry them out at a given time. This later condition may be come quite artificial, but might be informative in some cases.

A major variable in this type of task is the amount and type of intervening activity between the command and the execution. In fact, this is highly dependent on the scenario in which the test is embedded. Ultimately, the investigator will be able to introduce many kinds of interference during the delay period by requiring other flight tasks.

Experimenter Options.

The first task of the experimenter is to decide the type of information the subject must retain in memory. As noted above, three different levels of complexity could be defined (see Set Up Procedures). Each of these might show a different profile of G effects due to differences in working memory demand. Each also has a different applicability to operational tasks. Therefore, the experimenter might decide to include a balanced presentation of two or three of these types in order to be able to relate results to a range of operational missions.

A second option for the experimenter is the delay time between the command and the action. There may be some reason to differentiate between immediate memory processes that occur in less than about 20 seconds, and actual short term memory lasting longer than that. Therefore, the experimenter must decide whether to investigate both, or to focus on one. If longer durations are used, decisions must be made regarding the maximum time in the delay. Durations up to 20 minutes probably still probe pure short term memory, but beyond that, interpretation becomes more difficult.

Finally, the experimenter must decide what activities will be interpolated during the delay. As noted above, this will be constrained somewhat by the scenario location in which the probe is introduced. However, the range of activities is still quite broad. At the simplest level, routine straight and level flight might be introduced. At the other extreme, the experimenter might introduce a situation awareness question (Test 9) followed by an unusual attitude (Test 10) in the interval.

Anticipated Time to Administer This Test.

Obviously, the timing of this test is totally determined by the experimenter, and can range from a few seconds to more than 20 minutes. The only constraint is that the timing fit into the constraints of the scenario selected in Test 7 (Basis Flying Skills).

SUBJECT INSTRUCTIONS

Training Instructions.

If this test is to be used, the main points to be covered in these instructions all involve allowing the subject to know that the test is totally embedded into the flight scenario of Test 7 (Basic Flying Skills). In other words, the subject must know that the "commands" to carry out some later activity are actually part of the test. Otherwise, subjects might arbitrarily decide to ignore a command, thinking it had a low priority when he or she was preoccupied with another task. Subjects do not need to be told how many probes will be presented, and certainly not when they will appear, but they should know that their memory is being tested. Other than this, no actual training or practice on this task will be necessary in most cases, although the experimenter may decide to illustrate the required action with an example that is not going to be used in the experiment.

Test Instructions.

Again, once the subject knows that memory probes may appear in the test, no specific instructions are required.

RECOMMENDED DATA ANALYSIS

Data from F-PASS scenarios does not include any summary statistics. All analyses are conducted off-line after the end of the session. Various tools are available for processing the raw data. Data handling tools process the data into Excel files that may be further manipulated and input into other programs such as statistical packages.

The basic measures to be obtained in this task are absolute error in the timing of the response versus the required timing, and, in some cases, the accuracy of the response. Lapses, or failures to carry out the required action are also tabulated.

TEST 12 - VISUAL MONITORING

GENERAL TEST DESCRIPTION

In this test, the subject is required to monitor systems visually while performing normal flight functions as described in the Basic Flying Skills Scenario (Test 7). The test is presented with the F-16 cockpit visible. The basic concept is that any of four selected displays (dials or numerical information) will indicate a degraded condition in some system. The subject must first detect the degraded condition, and take an appropriate remedial action (switch activation or verbal response). Unlike dial movement in Test 5 (Peripheral Information Processing), movement of the dials will be very gradual. The goal is not to make the visual detection task a threshold detection task -- the displays should be relatively easy to detect if scanned properly. This test should therefore probe the "automatic" functions of working memory.

Essentially, the test is a visual detection task, although some simple decision processes may be employed. The researcher will be permitted to introduce the detection task at any point in the Basic Flying Skills mission, thereby determining the background workload level against which the task must be performed.

TECHNICAL SPECIFICATIONS OF THE TEST

In the default configuration, the critical cockpit displays are placed within the subject's parafoveal vision, with two on the left extreme of that range, and two on the right. With the Brooks centrifuge, the location of the displays is limited by the monitor size. At Wright Patterson, the displays can be located much further out in the periphery. However, since this is not necessarily a test of peripheral vision, they probably should normally be located less than 20 degrees in the periphery. Some of the displays provide numerical information (as opposed to moving dials).

The dials used for this test are the same ones used for Test 5 (Peripheral Information Processing), and are shown again below (figures 12-1 and 12-2). One additional type of display also will be used for this test. This is a numerical display consisting of a rectangular box measuring three inches in length and one inch in height. Inside the box, a three-digit number will be displayed, with the numbers approximately .75 inch high and spaced equally from the ends of the box and from each other. In experiments where this test is used, these dials are always present during the performance of the entire scenario used for Test 7 (Basic Flying Skills). However, they are not "integrated" into the cockpit display, but rather are simply superimposed in their appropriate locations (i.e., in some cases, the display might appear to be "floating in air" outside the cockpit. Although, in those cases, this will decrease the realism of the test, subjects should still be able to adapt, and monitor the displays, especially if they have had any experience with helmet-mounted displays.

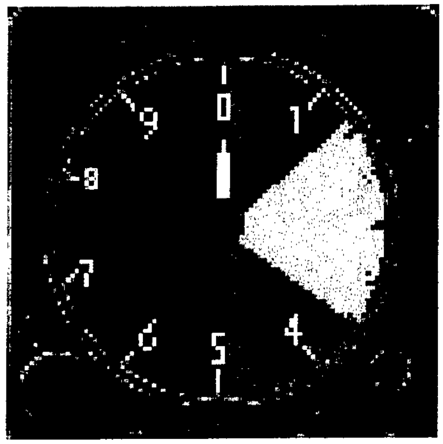

Figure 12-1. Round dial display to be monitored.

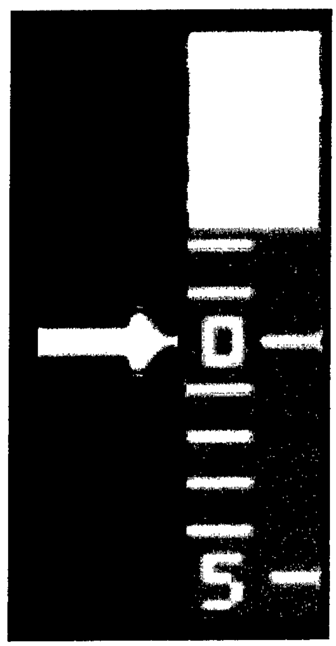

Figure 12-2. Vertical "strip" display to be monitored.

The round and vertical displays initially are always pointed at zero, and are in the green zone. They move slowly and continuously (approximately .1 inch/sec.) within that zone in both directions. In other words, they slowly oscillate within that zone in all the "normal" conditions. For the numerical display, the starting value is "500", and the numbers change slowly up and down (e.g., once per 2 seconds) in increments of ten.

The subject's task is to indicate detection of any deviation into the yellow zone for the round dial, either the red or yellow zone for the vertical dial, or values above 550 or below 450 for the numerical display. When an indicator is detected as out of range, designated buttons on the HOTAS joystick and throttle should be pressed to indicate which display is deviating, and in which direction. This "corrects the problem" and resets the indicators.

The experimenter designates when this test is to be given in the scenario. At that time, the random movement of any designated display within the "safe" zone ceases. In order to standardize the trials, the dial will always return to the zero position, and the numeric value will return to 500. At that time, the indicator will drift to the "out of range" position. The speed of this movement is the same as the speed used while the display was in the green zone.

The basic data of interest in this test is time to detect significant deviation in any display. In addition, the appropriateness or accuracy of the decision process is captured, and separate switches are defined for designating which display was out of limits. The time stamp of the display entering an abnormal condition and the time stamp of the subject's responses therefore form the basic data collected. These response times are labeled with respect to time into the mission, direction and type of display showing the abnormality, and the accuracy of the response.

WHEN TO USE THIS TEST

In this test, a goal is to probe the subject's attentional processes, including the ability to multiplex among various tasks. This is an important process to assess, since it has been shown that such things as scan patterns and attention to peripheral, rarely changing information sources change early under certain stresses. Therefore, this test is recommended whenever the researcher is interested in assessing long-duration effects of G forces. The test will probably be most useful (along with Test 7 - Basic Flying Skills) after the subject has been exposed to a particular acceleration profile. Pre-Post comparisons can then be made.

SET UP PROCEDURES FOR THIS TEST

Experimenter Options.

The experimenter is responsible for deciding how many of these probes to introduce, what type of information to present, and where to embed them into the scenario of Test 7.
As in other F-PASS-related tests, the experimenter must assure that the probes are presented at an appropriate time in the scenario of Test 7 (Basic Flying Skills).

Anticipated Time to Administer This Test.

Once the deviation is initiated, the test time is totally dependent on how long it takes the subject to correct the deviation. Normally, this would not be expected to take more than 30 seconds, but could be shorter or longer in some cases.

SUBJECT INSTRUCTIONS

Training Instructions.

DURING THE COURSE OF FLYING THE NAVIGATION SCENARIO, YOU WILL

SEE FOUR INFORMATION DISPLAYS SUPERIMPOSED IN FOUR CORNERS OF THE SCREEN (N.B., may have to illustrate for specific experimental set ups). WHILE FLYING, YOU ARE TO MONITOR THESE DISPLAYS FOR ANY "OUT OF RANGE" DEVIATIONS. THE INDICATORS WILL FLUCTUATE SLOWLY WITHIN "SAFE" ZONES, AND YOU DO NOT HAVE TO DO ANYTHING UNDER THESE CONDITIONS. HOWEVER, IF ANY INDICATOR ENTERS INTO AN "UNSAFE" ZONE (AS DESCRIBED BELOW), YOU ARE TO RESPOND BY PRESSING AN APPROPRIATE COMBINATION OF SWITCHES (WHICH WILL BE POINTED OUT TO YOU). THIS WILL "CORRECT" THE PROBLEM, AND THE DISPLAY SHOULD RETURN TO THE SAFE POSITION.

(The "safe" positions, as well as the "unsafe" positions should then be pointed out, along with the switch activations required for each dial.)

Test Instructions.

Other than re-familiarization with the dials to be used, the "safe" ranges, and the switch requirements, no specific instructions need to be given before the test.

RECOMMENDED DATA ANALYSIS

Data from F-PASS scenarios does not include any summary statistics. All analyses are conducted off-line after the end of the session. Various tools are available for processing the raw data. Data handling tools process the data into Excel files that may be further manipulated and input into other programs such as statistical packages.

The basic data of interest in this test are mainly time from the beginning of the deviation until the subject's first correct switch activation and the number of incorrect switch activations. However, the type and location of the display in which the deviation occurred is presented, along with summary information about how many times that display deviated, and separate response time averages for each type and position of the deviated display. This permits the interested experimenter to calculate considerable information about different kinds and locations of displays.

APPENDIX C

DESCRIPTION OF TEST PARAMETERS FOR THE G-PASS TEST BATTERY

This document is a description of the user changeable parameters available for each of the G-PASS tests. These parameters may be changed by manually editing the appropriate test battery database file (not recommended) or using the G-PASS Design and Configuration Programs. Only the parameters described here should be changed by the user. All other parameters are system related and should NOT be changed.

In the following sections, nnnn refers to a numeric integer, nn.nn is a real number with 2 decimal places, aaaaaaaa is an alphanumeric character string, and T/F indicates TRUE or FALSE. In all parameter listings, everything after "//" on a line is a comment.

STAND-ALONE TESTS

All stand-alone tests have some parameters in common as found in the startup section of the test battery database file. These include the following:

```
InstructionScreen=T/F      // TRUE to show the instruction screen before the test runs
                           // (used primarily for training). FALSE to bypass the
                           // instruction screen.

TimeLimited= T/F           // TRUE to run the test for a specified time. FALSE to run
                           // the tests for a specified number of trials.

Timeout=nn.nn              // If TimeLimited = TRUE, this specified the length of the
                           // trials.
```

Each of the stand-alone tests has an associated parameter list in the portion of the test battery database file that contains its parameters. All stand-alone tests have a group of common parameters that includes:

```
ShowBanner=T/F             // If TRUE, a banner identifying the test is shown when
                           // the test starts up. If FALSE, the banner is not shown.

NumTrials=nnnn             // If the test is being run a specified number of trials, this is
                           // the number of trials to run. If the test is being run a
                           // certain amount of time, this is the number of trials to run
                           // before generating a new stimulus order. If time runs out
                           // before nnnn trials, the test just ends. If the number of
                           // trials is reached before time is out, a new set of nnnn
                           // trials is generated and testing continues until time runs
                           // out.
```

Training=T/F	// If TRUE, the test will present an instruction screen before // running. FALSE skips the instruction screen.
ITIMin=nn.nn	// The minimum number of seconds in the Inter-Trial // Interval (ITI)
ITIMax=nn.nn	// The maximum number of seconds in the ITI
ITIInc=nn.nn	// The increment to be used when generating a randomly // selected ITI between ITImin and ITImax.

The following sections detail the parameters unique to each test. These parameters will be found in the test's sections of the test battery database.

Test 1: Perception of Relative Motion

```
LateralScale=nn.nn           // Joystick scaling factor for lateral movement of the
                             // target (default=15.0)

ThrottleScale=nn.nn          // Throttle scaling factor for speed of closure with the
                             // target (default=15.0)

Inertia=nn.nn                // Inertia scaling factor for movement of the target
                             // (default =1.0)

TgtSpeed=nn.nn               // Speed of the target during the trial (default=2.0)

StartThreshold=nn.nn         // Proportion of stick deflection required to indicate an
                             // intentional movement by the subject for recording first
                             // stick movement after the trial starts. Stick values are in
                             // the range 0-1. Therefore a StartThreshold value of 0.05 is
                             // equivalent of 1/20 of full stick deflection. (default=0.05)

EndThreshold=nn.nn           // Number of seconds the fighter must join to the green
                             // portion of the Tanker boom for successful docking.
                             // (default=2.0)

StartMin=nn.nn               // Minimum number of seconds from the start of the trial     // until
the target appears (default=2.0)

StartMax=nn.nn               // Maximum number of seconds from the start of the trial     // until
the target appears (default=5.0)

StartInc=nn.nn               // Increment in seconds for generating a random time
                             // between StartMin and StartMax from the start of the trial
                             // until the target appears (default=1.0)

EndDelay=nn.nn               // Number of seconds following successful joinup or failure
                             // that the images will stay on screen before starting the ITI
                             // (provides visual feedback to the subject). (default=2.0)

Timeout=nn.nn                // Number of seconds from the start of the trial until the     // trial
times out (default=45.0)

ScreenScale=nn.nn            // Scaling factor for the screen size for adjustment to the     //
display device. For a flat computer monitor, this factor
                             // should be 1.0. For the DES dome, this factor must be
                             // empirically determined. (default=1.0)

TimeLimited=T/F              // If the current session is to be run for a selected duration
```

// rather than a selected number of trials, this is set TRUE.
// (default=FALSE). This must always match the value of
// TimeLimited in the startup section of the test database
// file (see above).

Test 2: Precision Timing Task

IndPosMin=0.nn	// Minimum position of the stop indicator as a proportion of // the entire curve length of 1.0. (default=0.33)
IndPosMax=0.nn	// Maximum position of the stop indicator as a proportion // of the entire curve length of 1.0. (default=0.67)

IndPosInc=0.nnn	// Increment in position of the stop indicator when
	// generating a random position between IndPosMin and
	// IndPosMax, as a proportion of the entire curve length of
	// 1.0. (default=0.0167)

SpeedMin=nn.nn	// Minimum speed of the moving light. (default=2.0)
SpeedMax=nn.nn	// Maximum speed of the moving light. (default=4.0)
SpeedInc=nn.nn	// Speed increment for generating a random speed between // SpeedMin and SpeedMax (default=0.25)
ButtonDef=nnnn	// HOTAS button used to stop the moving light // (default=0, the "fire" button on the joystick)
EndDelay=nn.nn	// The number of seconds after the stop button has been\ // pressed before the screen is cleared. (default=2.0)

ScreenScale=nn.nn	// Scaling factor for the screen size for adjustment to the
	// display device. For a flat computer monitor, this factor
	// should be 1.0. For the DES dome, this factor must be
	// empirically determined. (default=0.5)

TimeLimited=T/F	// If the current session is to be run for a selected duration
	// rather than a selected number of trials, this is set TRUE.
	// (default=FALSE). This must always match the value of
	// TimeLimited in the startup section of the test database
	// file (see above).

Test 3: Motion Inference

HashMrkPosMin=0.nn	// Minimum position of the stop indicator as a proportion of // the entire curve length of 1.0. (default=0.50)
HashMrkPosMax=0.nn	// Maximum position of the stop indicator as a proportion // of the entire curve length of 1.0. (default=0.75)

HashMrkPosInc=0.nn	// Increment in position of the stop indicator when
	// generating a random position between IndPosMin and
	// IndPosMax, as a proportion of the entire curve length of
	// 1.0. (default=0.05)

SpeedMin=nn.nn	// Minimum speed of the moving light. (default=2.0)
SpeedMax=nn.nn	// Maximum speed of the moving light. (default=4.0)
SpeedInc=nn.nn	// Speed increment for generating a random speed between // SpeedMin and SpeedMax (default=0.25)
ButtonFalse=nnnn	// HOTAS button used to indicate NO vowel in the // letter task. (default=12)
ButtonTrue=nnnn	// HOTAS button used to indicate the presence of a // vowel in the letter task. (default=10)
ButtonLight=nnnn	// HOTAS button used to stop the moving light // (default=0, the "fire" button on the joystick)
ShowEndLight=T/F	// If TRUE, the position of the light will be shown at the // time the ButtonLight button is pressed. (default=TRUE)

EndLightDelay=nn.nn	// If ShowEndLight=TRUE, number of seconds after the
	// stop light response before the trial is removed from the
	// screen (default=0.5)

NoEndLightDelay=nn.nn	// If ShowEndLight=FALSE, number of seconds after the
	// stop light response before the trial is removed from the
	// screen. (default=0.5)

ScreenScale=nn.nn	// Scaling factor for the screen size for adjustment to the
	// display device. For a flat computer monitor, this factor
	// should be 1.0. For the DES dome, this factor must be
	// empirically determined. (default=0.5)

TimeLimited=T/F	// If the current session is to be run for a selected duration

// rather than a selected number of trials, this is set TRUE.
// (default=FALSE). This must always match the value of
// TimeLimited in the startup section of the test database
// file (see above).

Test 4: Pitch/Roll Capture

RollScale=nn.nn	// Scaling factor for movement in the horizontal direction. // (default=20.0)
PitchScale=nn.nn	// Scaling factor for movement in the vertical direction. // (default=10.0)

StartThreshold=nn.nn	// Proportion of stick deflection required to indicate an
	// intentional movement by the subject for recording first
	// stick movement after the trial starts. Stick values are in
	// the range 0-1. Therefore a StartThreshold value of 0.05 is
	// equivalent of 1/20 of full stick deflection. (default=0.05)

EndThreshold=nn.nn	// Number of seconds the subject must hold the center of
	// the target within the reticle for a successful capture.
	// (default=3.0)

StartMin=nn.nn	// Minimum time in seconds after the start of the trial that // the target appears. (default=1.0)
StartMax=nn.nn	// Maximum time in seconds after the start of the trial that // the target appears. (default=3.0)

StartInc=nn.nn	// Increment in seconds for generating a time between
	// StartMin and StartMax after the start of the trial when the
	// target appears. (default=0.5)

ButtonDef=nnnn	// The HOTAS button used to stop the moving light // (default=0, the "fire" button on the joystick)

ScreenScale=nn.nn	// Scaling factor for the screen size for adjustment to the
	// display device. For a flat computer monitor, this factor
	// should be 1.0. For the DES dome, this factor must be
	// empirically determined. (default=1.0)

Timeout=nn.nn	// Number of seconds from the start of the trial until the // trial times out (default=30.0)

TimeLimited=T/F	// If the current session is to be run for a selected duration
	// rather than a selected number of trials, this is set TRUE.
	// (default=FALSE). This must always match the value of
	// TimeLimited in the startup section of the test database
	// file (see above).

Test 5: Peripheral Vision

```
Dome=T/F                     // TRUE if using the DES dome (default=TRUE)

TargetBrightness=nn.nn       // Brightness of the target object(s). 0.0 = black,
                             // 1.0 = brightest. (default=1.0)

TargetLocation=(x1-x2,y1-y2) (x3-x4,y3-y4)
                             // Range of X,Y locations in the visual field to present the
                             // target (1-15 in X, 1-15 in Y). The two sets of arguments
                             // define left and right regions of the display.
                             // (default=(1-4,8) (12-15,8))

TargetDuration=nn.nn         // Duration of the target on the screen in seconds.
                             // (default=15.0)

TargetShowMin=nn.nn          // Minimum number of seconds into the trial at which the
                             // target appears (default=0.0)

TargetShowMax=nn.nn          // Maximum number of seconds into the trial at which the
                             // target appears (default=2.0)

TargetShowInc=nn.nn          // Increment in seconds for generating the time into the trial
                             // between TargetShowMin and TargetShowMax  at which
                             // the target appears (default=1.0)

TargetMoveMin=nn.nn          // Minimum time into the trial in seconds at which the
                             // target begins movement (default=5.0)

TargetMoveMax=nn.nn          // Maximum time into the trial in seconds at which the
                             // target begins movement (default=5.0)

TargetMoveInc=nn.nn          // Increment in seconds for generating the time into the trial
                             // between TargetMoveMin and TargetMoveMax  at which
                             // the target begins movement (default=0.0)

SpotTarget=T/F               // TRUE if the Spot target is to be presented. DialTarget
                             // and StripTarget must be FALSE. (default=TRUE)

DialTarget=T/F               // TRUE if the Dial target is to be presented. SpotTarget
                             // and StripTarget must be FALSE. (default=FALSE)

StripTarget=T/F              // TRUE if the Vertical Strip is to be presented. SpotTarget
                             // and DialTarget must be FALSE. (default=FALSE)

MirrorTarget=T/F             // TRUE if the selected target is to be mirrored on the
```

```
                    // opposite side. (default=TRUE)

SpotSpeed=nn.nn     // Speed of the spot in degrees/second (default=2.0)

PointerSpeed=nn.nn  // Speed of the pointer in degrees/second (default=5.0)

ButtonDetect=nnnn   // HOTAS button to indicate detection of target (default=0,
                    // the "fire" button)

ButtonLeft=nnnn     // HOTAS button to indicate left movement (default=13)

ButtonRight=nnnn    // HOTAS button to indicate right movement (default=11)

ButtonUp=nnnn       // HOTAS button to indicate up movement (default=10)

ButtonDown=nnnn     // Button to indicate down movement (default=12)

ButtonZone1=nnnn    // Button to indicate Zone1 location (default=6)

ButtonZone2=nnnn    // Button to indicate Zone2 location (default=7)

ButtonZone3=nnnn    // Button to indicate Zone3 location (default=8)

TimeLimited=T/F     // If the current session is to be run for a selected duration
                    // rather than a selected number of trials, this is set TRUE.
                    // (default=FALSE). This must always match the value of
                    // TimeLimited in the startup section of the test database
                    // file (see above).
```

Test 6: Rapid Decision Making

CircleSize=nn.nn	// Diameter of the outside circle in inches. (default=6.0)
SymbolSize=nn.nn	// Vertical Size of the symbols X,O,? in inches. // (default=0.33)
Button1=nnnn	// HOTAS button assigned to the symbol "X" (default=0)
Button2=nnnn	// HOTAS button assigned to the symbol "O" (default=1)
Button3=nnnn	// HOTAS button assigned to the symbol "?" (default=2)
TrainingDelay=nn.nn	// Length of time in seconds that feedback is displayed // (default=2.0)

ScreenScale=nn.nn	// Scaling factor for the screen size for adjustment to the
	// display device. For a flat computer monitor, this factor
	// should be 1.0. For the DES dome, this factor must be
	// empirically determined. (default=0.3)

Timeout=nn.nn	// Number of seconds from the start of the trial until the // trial times out (default=10.0)

TimeLimited=T/F	// If the current session is to be run for a selected duration
	// rather than a selected number of trials, this is set TRUE.
	// (default=FALSE). This must always match the value of
	// TimeLimited in the startup section of the test database
	// file (see above).

F-PASS TESTS

G-PASS tests that use the F-PASS flight simulator rely on several global parameters that are in the FPASS OPTIONAL and FPASS SIM sections of the test battery database. These globals include:

INFOSCREEN=T/F	// If TRUE, a screen of descriptive information about the
	// test to be given will be presented. Used for Training.
	// (default=FALSE)

Scenario=aaaaaaaa	// The name of the scenario to be run for this test. The
	// canned scenarios have names that match the test number.
	// For example, Gunsight Tracking (Test 8) uses the
	// scenario gpass_8. (default=scenarios/gpass_7)

SplashScreen=T/F	// If TRUE, the F-PASS splash screen will be shown and
	// the subject will have to press a button to proceed. Used
	//primarily for Training. (default=FALSE)

DoDome=T/F	// If TRUE, the system assumes it is being run in the DES
	// dome and uses the Elumens projection software.
	// (default=TRUE)

Each of the individual tests is associated with a parameter file that has the same base name as the scenario file. For example, the Basic Flying Skills Test (Test 7) has a scenario file named

gpass_7

and a parameter file named

gpass_7.txt

Each of the Tests in this section are built on the Basic Flying Skills scenario. Therefore, the parameters for each test include the Basic Flying Skills parameters as well. The following sections describe the parameter files for each of the F-PASS tests.

Test 7: Basic Flying Skills

// The scenario file is gpass_7 and the parameter file is gpass_7.txt.

StartingWayPoint=nnnn	// The waypoint where the scenario is to begin. In the Basic
	// Flying Skills scenario, there are 6 way points numbered
	// 1-6. (default=1)

EndingWayPoint=nnnn	// The waypoint at which the scenario is to end. (default=6)

Repeats=nnnn	// This is the number of times scenario repeats. Starting at
	// way point 3 and flying around to way point 1 is
	// considered a repeat. (default=0)

WindEnabled=T/F	// If TRUE, a simulated wind blowing of Eastward wind at // 20 knots is enabled. (default=FALSE)

InstructionFile1=aaaaaaaa	// the name of the file for the first auditory instruction in the
	// Basic Flying Skills scenario.
	// (default=resources\temp\inst1.wav)

InstructionFile2=aaaaaaaa	// the name of the file for the second auditory instruction in
	// the Basic Flying Skills scenario.
	// (default=resources\temp\inst2.wav)

InstructionFile3=resources\temp\INST3.WAV

// the name of the file for the third auditory instruction in
// the Basic Flying Skills scenario.
// (default=resources\temp\inst3.wav)

Test 8: Gunsight Tracking

// The scenario file is gpass_8 and the parameter file is gpass_8.txt.

// Basic Flying parameters

StartingWayPoint=nnnn // The waypoint where the scenario is to begin. In the Basic // Flying Skills scenario, there are 6 way points numbered // 1-6. (default=3)

EndingWayPoint=nnnn // The waypoint at which the scenario is to end. (default=4)

Repeats=nnnn // This is the number of times scenario repeats. Starting at // way point 3 and flying around to way point 1 is // considered a repeat. (default=0)

WindEnabled=T/F // If TRUE, a simulated wind blowing of Eastward wind at // 20 knots is enabled. (default=FALSE)

InstructionFile1=aaaaaaaa // the name of the file for the first auditory instruction in the // Basic Flying Skills scenario. // (default=resources\temp\inst1.wav)

InstructionFile2=aaaaaaaa // the name of the file for the second auditory instruction in // the Basic Flying Skills scenario. // (default=resources\temp\inst2.wav)

InstructionFile3=resources\temp\INST3.WAV
// the name of the file for the third auditory instruction in // the Basic Flying Skills scenario. // (default=resources\temp\inst3.wav)

// Gunsight Tracking parameters

ButtonName=aaaaaaaa // The name of the HOTAS trigger button. // (default=TRIGGER_BTN_1)

TrackNumber=nnnn // The number of tracking instances in this scenario // (default=1)

// Definition of the first tracking segment

WayPoint=nnnn // The starting way point for this scenario. Tracking will // start AFTER this way point. (default=3)

Distance=nn.nn // The distance, in nautical miles AFTER WayPoint where

```
                        // tracking will begin. If no Distance is desired, set = 0.0.
                        // (default=0.0)

Time=nn.nn              // The time AFTER WayPoint at which the tracking will
                        // begin. If no Time is desired, set = 0.0. (default=3.0)

// NOTE: If a Distance only is desired, set Time=0.0. If a Time only is desired, set
// Distance=0.0. If both Time and Distance are > 0.0, then which ever comes first will be
// performed and the other value ignored.

PointNumber=nnnn        // The number of G value changes for this tracking
                        // instance. The following points MUST be on consecutive
                        // lines with no intervening blank or comment lines.
                        // (default=10)

Point0=nn.nn nn.nn nnnn // First G value.
                        // Argument1=G value (>= 1.0). (default=0.0)
                        // Argument 2=time in seconds at this G value(default=1.0)
                        // Argument #3=G direction (-1 left, 0 straight, 1 right).
                        // (default=0)

Point1=2.0 2.0 -1
Point2=3.0 3.0 -1
Point3=6.0 2.0 -1
Point4=8.0 1.0  0
Point5=10.0 1.0  0
Point6=12.0 2.0  1
Point7=14.0 3.0  1
Point8=16.0 2.0  1
Point9=18.0 1.0  0

// Additional tracking segments are specified here (way point, distance, time, points).
```

Test 9: The Blanking Test for Assessing Situation Awareness

// The scenario file is gpass_9 and the parameter file is gpass_9.txt.

// Basic Flying parameters

```
StartingWayPoint=nnnn       // The waypoint where the scenario is to begin. In the Basic
                            // Flying Skills scenario, there are 6 way points numbered
                            // 1-6. (default=3)

EndingWayPoint=nnnn         // The waypoint at which the scenario is to end. (default=4)

Repeats=nnnn                // This is the number of times scenario repeats. Starting at
                            // way point 3 and flying around to way point 1 is
                            // considered a repeat. (default=0)

WindEnabled=T/F             // If TRUE, a simulated wind blowing of Eastward wind at
                            // 20 knots is enabled. (default=FALSE)

InstructionFile1=aaaaaaaa   // the name of the file for the first auditory instruction in the
                            // Basic Flying Skills scenario.
                            // (default=resources\temp\inst1.wav)

InstructionFile2=aaaaaaaa   // the name of the file for the second auditory instruction in
                            // the Basic Flying Skills scenario.
                            // (default=resources\temp\inst2.wav)

InstructionFile3=resources\temp\INST3.WAV
                            // the name of the file for the third auditory instruction in
                            // the Basic Flying Skills scenario.
                            // (default=resources\temp\inst3.wav)
```

// Situational Awareness Test parameters

```
ButtonNameYes=aaaaaaaa      // The name of the HOTAS button for a YES/TRUE
                            // response. (default=TRIGGER_BTN_1)

ButtonNameNo=aaaaaaaa       // The name of the HOTAS button for a NO/FALSE
                            // response. (default=TRIGGER_BTN_2)

WayPoint=nnnn               // The starting way point for this scenario. (default=1)

SAnumber=nnnn               // The number of SA questions to be presented in this
                            // scenario. (default=3)
```

// NOTE: The following waypoint/distance/time parameters define when the SA

// questions are presented.

```
WP1=nnnn               // Waypoint where the 1st SA question is given. The
                       // question will be given AFTER this waypoint is passed.
                       // (default=1)

Distance1=nn.nn        // The distance, in nautical miles AFTER WP1 where the
                       // SA question will be presented. If no Distance is desired,
                       // set = 0.0. (default=0.0)

Time1=nn.nn            // The time AFTER WP1 at which the SA question will
                       // be presented. If no Time is desired, set = 0.0.
                       // (default=3.0)

// NOTE: If a Distance only is desired, set Time=0.0. If a Time only is desired, set
// Distance=0.0. If both Time and Distance are > 0.0, then which ever comes first will be
// performed and the other value ignored.

Q1=nnnn                // SA question number to be presented. (default=1)

WP2=nnnn               // Parameters for SA question 2
Distance2=nn.nn
Time2=nn.nn
Q2=nnnn

WP3=nnnn               // Parameters for SA question 3
Distance3=nn.nn
Time3=nn.nn
Q3=nnnn.

// Additional SA questions would be defined here.
```

Test 10: Unusual Attitude Recovery

// The scenario file is gpass_10 and the parameter file is gpass_10.txt.

// Basic Flying parameters

StartingWayPoint=nnnn	// The waypoint where the scenario is to begin. In the Basic // Flying Skills scenario, there are 6 way points numbered // 1-6. (default=3)
EndingWayPoint=nnnn	// The waypoint at which the scenario is to end. (default=4)
Repeats=nnnn	// This is the number of times scenario repeats. Starting at // way point 3 and flying around to way point 1 is // considered a repeat. (default=0)
WindEnabled=T/F	// If TRUE, a simulated wind blowing of Eastward wind at // 20 knots is enabled. (default=FALSE)
InstructionFile1=aaaaaaaa	// the name of the file for the first auditory instruction in the // Basic Flying Skills scenario. // (default=resources\temp\inst1.wav)
InstructionFile2=aaaaaaaa	// the name of the file for the second auditory instruction in // the Basic Flying Skills scenario. // (default=resources\temp\inst2.wav)

InstructionFile3=resources\temp\INST3.WAV
// the name of the file for the third auditory instruction in
// the Basic Flying Skills scenario.
// (default=resources\temp\inst3.wav)

// Unusual Attitude Test parameters

SA=T/F	// TRUE if UAs are to follow SA questions. // (default=FALSE)

// NOTE: If SA=TRUE then the parameters for the SA test need to be configured. See the
// description for Test 9, Situational Awareness.

WayPoint=nnnn	// The starting way point for this scenario. (default=1)
UAnumber=nnnn	// The number of UAs to be presented in this scenario. // (default=1)
WP1=nnnn	// Waypoint for the first UA. The UA will be presented

	// AFTER passing this waypoint. (default=1)
Distance1=nn.nn	// The distance, in nautical miles AFTER WP1 where the // UA will be presented. If no Distance is desired, // set to 0.0. (default=0.0)
Time1=nn.nn	// The time AFTER WP1 at which the UA will // be presented. If no Time is desired, set to 0.0. // (default=3.0)

// NOTE: If a Distance only is desired, set Time=0.0. If a Time only is desired, set
// Distance=0.0. If both Time and Distance are > 0.0, then which ever comes first will be
// performed and the other value ignored.

//Additional UA instances (WPn, Distancen, Timen) are defined here.

Test 11: Short-Term Memory

// The scenario file is gpass_11 and the parameter file is gpass_11.txt.

// Basic Flying parameters

StartingWayPoint=nnnn	// The waypoint where the scenario is to begin. In the Basic // Flying Skills scenario, there are 6 way points numbered // 1-6. (default=3)
EndingWayPoint=nnnn	// The waypoint at which the scenario is to end. (default=4)
Repeats=nnnn	// This is the number of times scenario repeats. Starting at // way point 3 and flying around to way point 1 is // considered a repeat. (default=0)
WindEnabled=T/F	// If TRUE, a simulated wind blowing of Eastward wind at // 20 knots is enabled. (default=FALSE)
InstructionFile1=aaaaaaaa	// the name of the file for the first auditory instruction in the // Basic Flying Skills scenario. // (default=resources\temp\inst1.wav)
InstructionFile2=aaaaaaaa	// the name of the file for the second auditory instruction in // the Basic Flying Skills scenario. // (default=resources\temp\inst2.wav)

InstructionFile3=resources\temp\INST3.WAV
// the name of the file for the third auditory instruction in
// the Basic Flying Skills scenario.
// (default=resources\temp\inst3.wav)

// Short-Term Memory Test parameters

WayPoint=nnnn	// The starting way point for this scenario. (default=1)
STMnumber=nnnn	// The number of Short-Term Memory instances to be // presented in this scenario. (default=1)
STMfile1=aaaaaaaa	// Path/Name of the WAV file containing the audio for // STM1. (default=scenarios\temp\stm1.wav)
WP1=nnnn	// Waypoint for the first STM. The STM audio will be // presented AFTER passing this waypoint. (default=1)
Distance1=nn.nn	// The distance, in nautical miles AFTER WP1 where the

	// STM audio will be presented. If no Distance is desired, // set to 0.0. (default=0.0)

Time1=nn.nn	// The time AFTER WP1 at which the STM audio will
	// be presented. If no Time is desired, set to 0.0.
	// (default=3.0)

// NOTE: If a Distance only is desired, set Time=0.0. If a Time only is desired, set
// Distance=0.0. If both Time and Distance are > 0.0, then which ever comes first will be
// performed and the other value ignored.

//Additional STM instances (STMfilen, WPn, Distancen, Timen) are defined here.

Test 12: Visual Monitoring

// The scenario file is gpass_12 and the parameter file is gpass_12.txt.

// Basic Flying parameters

StartingWayPoint=nnnn	// The waypoint where the scenario is to begin. In the Basic // Flying Skills scenario, there are 6 way points numbered // 1-6. (default=3)
EndingWayPoint=nnnn	// The waypoint at which the scenario is to end. (default=4)
Repeats=nnnn	// This is the number of times scenario repeats. Starting at // way point 3 and flying around to way point 1 is // considered a repeat. (default=0)
WindEnabled=T/F	// If TRUE, a simulated wind blowing of Eastward wind at // 20 knots is enabled. (default=FALSE)
InstructionFile1=aaaaaaaa	// the name of the file for the first auditory instruction in the // Basic Flying Skills scenario. // (default=resources\temp\inst1.wav)
InstructionFile2=aaaaaaaa	// the name of the file for the second auditory instruction in // the Basic Flying Skills scenario. // (default=resources\temp\inst2.wav)

InstructionFile3=resources\temp\INST3.WAV

// the name of the file for the third auditory instruction in // the Basic Flying Skills scenario. // (default=resources\temp\inst3.wav)

// Visual Monitoring Test parameters

WayPoint=nnnn	// The starting way point for this scenario. (default=1)
VMnumber=nnnn	// The number of Visual Monitoring instances to be // presented in this scenario. (default=1)
VMdial1=nnnn	// Number of the instrument that is to show an // abnormality in this segment. (default=1)
WP1=nnnn	// Waypoint for the first VM incident. The VM incident // will start AFTER passing this waypoint. (default=1)
Distance1=nn.nn	// Distance, in nautical miles AFTER WP1 where the

// VM incident will start. If no Distance is desired,
// set to 0.0. (default=0.0)

Time1=nn.nn // The time AFTER WP1 at which the VM incident will
// start. If no Time is desired, set to 0.0. (default=3.0)

// NOTE: If a Distance only is desired, set Time=0.0. If a Time only is desired, set
// Distance=0.0. If both Time and Distance are > 0.0, then which ever comes first will be
// performed and the other value ignored.

//Additional VM instances (VMdialn, WPn, Distancen, Timen) are defined here.